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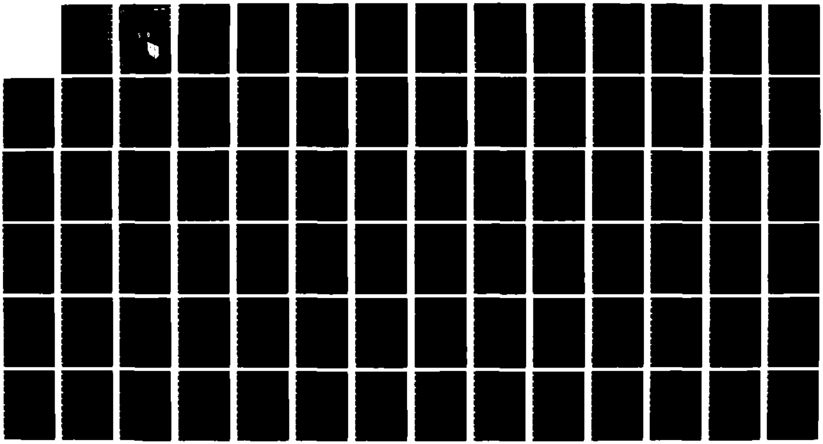

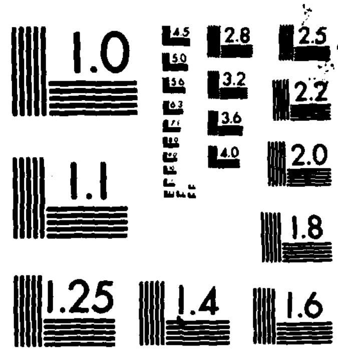

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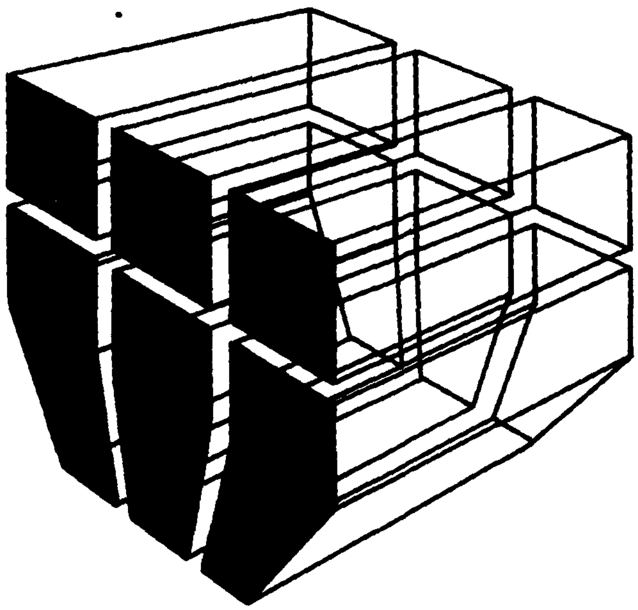
TECHNICAL REPORT N-86/19
July 1986
Sanitary Landfill Leachate Control
at Military Installations

AD-A172 105

Management of Leachate From Army Sanitary Landfills

by
William P. Gardiner
Stephen W. Maloney



This report provides information on landfill leachate management that will be useful to installation environmental coordinators and other management personnel. The information will be helpful for identifying leachate problems and locating data and technical assistance for solving these problems. Information is also provided to help personnel who must establish a new sanitary landfill requiring leachate control or investigate possible problems with older or inactive landfills.

Specific information is provided on regulatory requirements and responsibilities, landfill design and operation, leachate and gas production and control in both old and new landfills, and sources of information and assistance.

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Specific information is provided on regulatory requirements and responsibilities, landfill design and operation, leachate and gas production and control in both old and new landfills, and sources of information and assistance.

FOREWORD

This research was conducted for the Office of the Chief of Engineers (OCE) under Project 4A162720A896, "Environmental Quality Technology"; Task A, "Installation Environmental Management"; Work Unit 033, "Sanitary Landfill Leachate Control at Military Installations." The work was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The OCE Technical Monitor was Mr. F. Bizzoco, DAEN-ECE-G.

Mr. Robert E. Riggins is Acting Chief of USA-CERL-EN. Col Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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MANAGEMENT OF LEACHATE FROM ARMY SANITARY LANDFILLS

1 INTRODUCTION

Background

Leachate production--the dissolution of soluble constituents and the introduction of microbial byproducts into water--is a natural consequence of operating a sanitary landfill. The amount and characteristics of the leachate produced depend primarily on the contents of the wastes being disposed, the geologic and hydrologic characteristics at the disposal site, the precipitation pattern, and the region's climate. Generally, the potential for leachate formation is greatest in humid areas where rainfall is plentiful, and in landfills where groundwater lies near the surface.

Before World War II, the Army usually disposed of refuse on land (open dumps) in remote areas of the installation and burned the combustible materials periodically. The Army did not adopt sanitary landfilling as a solid waste disposal practice until 1942, when published instructions recommended that refuse be compacted into trenches and covered daily with soil. In 1946, the Army published Technical Manual (TM) 5-634, *Refuse Collection and Disposal*, which provided specific guidance. At that time, the primary emphasis of waste disposal was to reduce garbage odors and blowing litter and to control insects and rodents.

The 1958 version of TM 5-634 was the first Army guidance to address landfill site selection. Although site selection criteria dealt mainly with distance to refuse sources and access to the site, the manual did indicate that landfill sites should not have surface or subsurface drainage that might pollute a water supply.

These practices were undoubtedly considered "state of the art" and environmentally safe at that time. This view prevailed, even though it was common practice to co-dispose waste engine oil, spent solvents, industrial sludges, and municipal-type wastes. Furthermore, no one considered that these liquids might escape from a landfill and seriously contaminate surface waters or subsurface aquifers or otherwise harm the natural environment. Because of past practices, many of these old "sanitary landfills" are now being found to be "hazardous waste sites."

All Army landfills, whether old or new, closed or active, generate leachate. However, those with the greatest potential for producing leachate are on installations in the eastern and southeastern sections of the country and on the west coast--areas where rainfall is significant. Furthermore, it is the older or closed landfills in these areas that produce the most serious pollution problems. This observation has been substantiated by the Army Environmental Health Agency (AEHA).

The responsibility for Army groundwater quality monitoring has recently been assigned to the AEHA. This effort, called the Groundwater Monitoring Program, involves establishing a data file of test results on water samples from all Army wells, assessing water quality changes, and verifying compliance with National Drinking Water Standards. Preliminary results obtained in this program on water quality test data from monitoring wells at 19 active landfill sites on 15 Army installations found no significant groundwater contamination produced by currently active landfills but did find contamination from old landfills at several Army installations.

Water quality test results from monitoring wells installed in accordance with initial installation restoration studies (Phase I Reports) by the U.S. Army Toxic and Hazardous Material's Agency (USATHAMA) provided evidence of leachate contamination. In some cases, the leachate contained significant amounts of organics originating from the co-disposal of waste oils and solvents with installation refuse. As more test data from monitoring wells are evaluated, more leachate-contaminated landfill sites are expected to be identified.

Most Army installations with a groundwater contamination problem caused by a sanitary landfill have been identified from preliminary investigations. However, only at one--Fort Dix--have follow-on confirmation investigations been conducted. There are no instances where corrective action has been identified or initiated.

Objective

The objective of this report is to provide a management document on landfill leachate that will be useful as a reference and guide for installation environmental coordinators and other mid-level managers. The document provides (1) guidance in identifying a problem and locating necessary data and technical assistance to solve it, and (2) information to assist personnel who must establish a new sanitary landfill requiring leachate control or investigate potential problems with older active or inactive landfills.

Approach

Aspects of landfill design and operations, including solid waste classification, landfill siting, landfill classification, landfill design data and criteria, landfill operating and closure plans are discussed briefly to provide general background information. Leachate production and characteristics for new and old landfills are summarized, including control methodologies, treatment, monitoring, and investigative techniques. Sources of information about local regulations, Federal requirements, and technical assistance are summarized in a series of directories. These directories will help managers acquire the necessary resources to solve landfill leachate problems.

Scope

The information in this report is limited to fixed installations in the United States and its possessions. Design information and leachate production characteristics may also be applicable to installations outside the Continental United States, but local regulations and host government requirements are not addressed. The information is intended to serve as a starting point in identifying and resolving landfill leachate problems and therefore avoids highly technical language and details.

Mode of Technology Transfer

It is recommended that the information in this report be used to revise TMs on Army solid waste disposal, specifically TM 5-634, *Refuse Collection and Disposal: Repairs and Utilities* and TM 5-814-5, *Sanitary Landfill.*

2 REGULATORY REQUIREMENTS AND RESPONSIBILITIES

Owners and operators of sanitary landfills must comply with a variety of regulations. This chapter provides an overview of applicable regulations.

The reader should be aware that new sanitary landfills are subject to "solid waste" regulations. However, old or closed landfills, particularly those suspected of containing hazardous or toxic materials, may require actions based on "hazardous waste regulations."

Federal Regulations

Requirements for controlling leachate from sanitary landfills are based on several Federal laws and regulations. For the design and operation of new landfill sites, the U.S. Environmental Protection Agency (USEPA) has published *Guidelines for the Thermal Processing of Solid Wastes and for the Land Disposal of Solid Wastes* (40 CFR 240 and 241). These guidelines implemented the Solid Waste Disposal Act of 1965 as amended by the Resource Recovery Act of 1970. These regulations, which are mandatory for Federal agencies, require control of leachate to prevent degradation of surface and groundwater quality. Another USEPA regulation, 40 CFR 257, *Criteria for Classification of Solid Waste Disposal Facilities and Practices* provides guidance on evaluating existing landfill sites to determine if they are suitable for continued use. In essence, this regulation states that landfills that pollute surface waters or contaminate underground drinking water sources should be considered "open dumps" and therefore must be either upgraded or safely closed.

Landfills that release leachate into surface waters or underground drinking water sources can be subject to the provisions of either the Clean Water Act or the Safe Drinking Water Act (SWDA). For example, leachate discharged into surface waters may require a National Pollutant Discharge Elimination System (NPDES) permit and the leachate may have to be treated before discharge. On the other hand, if leachate is contaminating an underground drinking water source so that drinking water standards are being violated, the landfill owner could be cited for violating SDWA regulations. Remedial action could be required under either SDWA or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), referred to as the "Superfund Law," depending on whether the contaminant entering the groundwater is determined to be a priority hazardous pollutant.

State Regulations

Enforcement of Federal solid waste regulations is now delegated to the states. The law delineating state responsibilities is the Resource Conservation and Recovery Act (RCRA). The mechanism used to discharge this responsibility is the Solid Waste Management Plan, developed by a state and approved by USEPA. An outgrowth of these management plans is definitive state regulations that prescribe design and operating standards for landfills. Most state regulations also require that every landfill operator obtain a permit for each facility and that a registered professional engineer design the disposal facilities.

Most states have also issued separate regulations on hazardous waste management. Consequently, whenever a leachate release contains a hazardous substance, corrective action will be required and will be guided primarily by these regulations.

Army Regulations and Publications

Chapter 6 of Army Regulation (AR) 200-1, *Environmental Protection and Enhancement* (June 1982) provides basic Army policy and guidance on solid waste management. Army Pamphlet (PAM) 420-47, *Military Solid Waste Management* (June 1978) gives detailed procedures related to the collection, storage, and disposal of solid waste. However, these documents provide little information on the requirement to control leachate; consequently, managers of solid waste activities at Army installations must refer to state authorities and state regulations to determine if leachate control is required.

Army agencies have published numerous technical documents on landfill design and technologies, leachate production, control, and treatment, and gas production and control. The references at the end of this document provide sources for information on landfill technology.

Some of the most useful sources of information on leachate and its control include the four reports described below.

Characteristics, Control, and Treatment of Leachate at Military Installations[1]

This report provides introductory information about the generation of leachate and its characteristics, particularly its effects on human health and the environment. Guidance is provided on detecting leachate, monitoring leachate in groundwater, methods of controlling production, and various technologies for its treatment and disposal.

Treatment of Landfill Leachate at Army Facilities[2]

This report contains detailed information about technologies available for treating leachate that will allow safe disposal of the effluent. Treatment technologies covered include physical, chemical, and biological processes.

Landfill Liners and Covers: Properties and Application to Army Landfills[3]

This report provides information on the characteristics and applications of various types of liners and covers that can be used for landfills. Subjects discussed include the design and installation of liners and caps constructed from clays, synthetic membranes, asphalt, and admixed materials.

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[1] W. J. Mikucki, et al., *Characteristics, Control, and Treatment of Leachate at Military Installations*, Interim Report N-97/ADA097935 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1980).

[2] J. T. Bandy, et al., *Treatment of Landfill Leachate at Army Facilities*, Technical Report N 155/ADA132483 (USA-CERL, 1983).

[3] R. A. Shafer, et al., *Landfill Liners and Covers: Properties and Application to Army Landfills*, Technical Report N-183/ADA144003 (USA-CERL, 1984).

Landfill Gas Control at Military Installations[4]

This report provides information useful to Army personnel responsible for recognizing and solving potential problems from gas generated by landfills. Information is provided on recognizing and gauging the magnitude of landfill gas problems; selecting appropriate gas control strategies, procedures, and equipment; use of computer modeling to predict gas production and migration and the success of gas control devices; and safety considerations.

Responsibility for Remedial Action for Leachate Contamination

The Army is responsible for remedial action to correct the cause and repair the ecological damage resulting from the operation of any Army sanitary landfill. Regardless of the severity of the hazard, Superfund monies will not be available from USEPA for cleanup operations or investigations. However, the Defense Environmental Restoration Fund (DERF) may provide funds for these purposes. Any time the Army must take action to correct a contamination problem, special dispensation should not be expected from USEPA or a state just because the problem is on Federal property. Consequently, it is wise *not* to plan on taking any shortcuts. Instead, one should anticipate that remedial work will be costly, and expect a short, inflexible compliance schedule. Requests for DERF funding to correct a serious leachate contamination problem should be prepared at the installation and forwarded through channels to Headquarters, U.S. Army Corps of Engineers (ATTN: DAEN-ZCE) along with a project justification.

Superfund—National Priority List

A state or the USEPA may nominate solid and hazardous waste disposal sites considered to be a significant health and/or environmental hazard for inclusion in the National Priority List (NPL). To date, several Army disposal sites have been nominated to the NPL, but have not become eligible for Superfund financial assistance. Whenever an Army site is nominated for the NPL, it tends to focus national attention on the situation. Prompt cleanup action is usually demanded and the necessary funds for this work will probably be provided from the DERF.

When the USEPA or state authorities direct attention to a contaminated site, particularly one affecting groundwater, the media frequently publicize the matter. This, in turn, gives rise to inquiry by congressional and other local political representatives and evokes expressions of concern among the public about the possible impact on health and welfare. Under these circumstances, it is most prudent that the responsible staff agency at the affected installation promptly take action to: (1) request technical assistance from available Army agencies, (2) coordinate a plan of action with state authorities, and (3) execute the approved remedial action without delay.

Consideration should also be given to countering any adverse publicity with Army-initiated press and news releases that present the facts and explain the corrective measures being taken or to be taken.

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[4] R. A. Shafer, et al., *Landfill Gas Control at Military Installations*, Technical Report N-173/ADA140190 (USA-CERL, 1984).

3 OVERVIEW OF LANDFILL DESIGN AND OPERATION

Since the enactment of the RCRA in 1976, much more care is used to collect and dispose of solid wastes. The haphazard dumping of waste in remote areas of an installation without concern for protecting the environment or nearby off-post areas is no longer acceptable. Instead, Army installations must now closely manage solid wastes. This requirement involves compliance with applicable regulations on solid waste collection, disposal, and recycling (i.e., Federal regulations and the state regulations in which an installation is located).[5]

In states requiring permits to construct and operate landfills, Army installations must comply with state-prescribed procedures. Furthermore, plans for the design, construction, and operation of new landfill sites or modifications to existing sites must now be prepared or approved by a professional engineer registered in the state in which the facility will be constructed or operated.[6]

Since stricter controls are being imposed on solid waste management, responsible individuals at Army installations will find the following discussion of waste management considerations of value.

Solid Waste Classification

States usually classify solid waste to prescribe the type of landfill to be used for their disposal. Classification systems vary among states, but most divide solid waste into three broad groups:

GROUP I: Wastes consisting of or containing hazardous/toxic substances that could significantly impair the quality of usable waters.

GROUP II: Biologically and chemically decomposable material that does not include hazardous/toxic substances or materials that could significantly impair the quality of usable waters.

GROUP III: Insoluble, nondecomposable inert solids such as dirt, bricks, and pieces of broken concrete.

The Army does not have its own separate classification system. Consequently, the relevant state's solid waste regulations would apply. On the other hand, the Army has prescribed special measures that must be observed for disposal of certain military-unique wastes. According to Chapter 6 of AR 200-1, the following wastes may not be landfilled.

- Chemical warfare agents
- Explosive ordnance
- Pharmaceutical stocks and biological wastes
- Radioactive wastes.

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[5]Army Regulation (AR) 200-1, *Environmental Protection and Enhancement* (Department of the Army [DA], June 1982), paragraph 6-3.

[6]AR 420-47, *Solid and Hazardous Waste Management* (DA, December 1984), paragraph 4-6.

Landfill Siting

To avoid adverse affects on public health and the environment, USEPA has published guidelines in 40 CFR 257 that were intended for use in evaluating the acceptability of existing landfills.

These provisions should be used as a checklist in evaluating candidate sites for new landfills. Violation of any of the criteria below can result in a state or Federal order to close or upgrade the facility.

Flood Plains

Landfill facilities or practices in flood plains shall not restrict the flow of the base flood, reduce the flood plain's temporary water storage capacity, or result in washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources.

Endangered Species

Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife, nor result in the destruction or adverse modification of the critical habitat of officially designated endangered or threatened species.

Surface Water

Facilities or practices shall not cause a discharge of pollutants into state waters that violates NPDES requirements under Section 402 of the Clean Water Act, as amended.

Facilities or practices shall not cause a discharge of dredged material or fill material into state waters that violates requirements under Section 404 of the Clean Water Act, as amended.

Facilities or practices shall not cause nonpoint source pollution of state waters that violates applicable legal requirements implemented by a water quality management plan approved by the USEPA Administrator under Section 208 of the Clean Water Act, as amended.

Groundwater

Facilities or practices shall not contaminate an underground drinking water source within or beyond the solid waste boundary or beyond an alternative boundary specified by the responsible state authority. (Most state regulations specify a minimum distance between the waste and the groundwater table.)

Food-Chain Crops

Solid waste will not be disposed of within 3 ft* of the surface of land used to produce food-chain crops, unless the application of cadmium from solid waste complies with standards established by USEPA (40 CFR 257).

*Metric conversion factors are provided on p 62.

Solid waste containing concentrations of polychlorinated biphelnys (PCBs) equal to or greater than 10 mg/kg (dry weight) should not be incorporated into the soil of land used to produce animal feed, including pasture crops for animals raised for milk.

The solid waste need not be incorporated into the soil if it is certain that the PCB content is less than 0.2 mg/kg (actual weight) in animal feed or less than 1.5 mg/kg (fat basis) in milk.

Disease

There will be no disposal unless the on-site population of disease vectors is minimized to protect public health through periodic application of cover material or other techniques.

There will be no disposal of sewage sludge or septic tank pumpings unless the facilities or practices comply with USEPA (40 CFR 257) standards.

Air

There will be no open burning of residential, commercial, institutional, or industrial solid waste. This requirement does not apply to infrequent burning of agricultural wastes in the field, silviculture wastes for forest management purposes, land-clearing debris, diseased trees, and debris from emergency cleanup operations.

Facilities or practices shall not violate applicable requirements established by the State Air Pollution Control Authority.

Safety

The concentration of explosive gases generated by the facilities or practices shall not exceed:

- Twenty-five percent of the lower explosive limits for the gases in facility structures (excluding gas control or recovery system components); and

- The lower explosive limit for the gases at the property boundary.

Facilities or practices shall not endanger people or property from fires.

Facilities or practices for disposal of putrescible wastes that may attract birds and that occur within 10,000 ft of any airport runway used by turbojet aircraft, or within 5000 ft of any airport runway used by only piston-type aircraft, shall be operated and maintained so as not to endanger aircraft due to the presence of birds.

Facilities or practices shall not allow uncontrolled access at the disposal site that will expose the public to potential health and safety hazards.

Landfill Classification

Landfills are broadly classified as single-purpose or multipurpose. When used to dispose of only Group II or Group III (see p 12 for definitions) solid waste, a landfill is termed single-purpose. When both groups of waste are co-disposed, the landfill is multipurpose. The landfill is also considered multipurpose when the appropriate authority approves disposal of sewage sludge or flyash along with Group II waste.

Landfill Design Data and Criteria

State regulations provide general design criteria for the different types of authorized landfills. These criteria must be conscientiously observed by the design engineer, since the permit for each new or any upgraded disposal facility will usually not be issued unless state criteria are met or a variance/exemption is granted.

Before a new landfill design is begun, considerable geophysical information about the site must be developed. Often, the new data must be presented to the state permit issuing authority. The design engineer and the installation must generally compile the following types of information; all of these documents may be required by current state regulations.

- Site map showing facility location, nearest occupied buildings, surface water courses, airfields, and proposed borrow areas
- Site soils analysis
- Site hydrogeologic report
- Environmental impact analysis of proposed landfill operations
- Post-closure site utilization plan.

Although landfill design criteria vary among locations, most states require the design engineer and the installation to address the following requirements in the planning stage.

- A survey benchmark must be established and maintained on a landfill site.
- Leachate from a disposal facility must not drain or discharge into surface waters unless specifically authorized under an NPDES permit.
- Baseline water quality conditions reflecting annual seasonal conditions of both groundwater and surface water must be established before depositing any waste at a new landfill site.
- Groundwater monitoring wells must be installed. Usually, at least two wells must be located down-gradient from the fill area.
- Decomposition gases from within a landfill must be controlled to prevent hazards to health, safety, and property. Gas venting and monitoring procedures may be required.
- Drainage structures must be installed when the landfill site is established and must be continuously maintained to prevent ponding and erosion and to minimize infiltration of water into solid waste cells.
- Landfill sites must be fenced and equipped with a controlled access (gates, guard, etc.) to prevent unauthorized entry and dumping.

Landfill Operating Plan

Besides the engineering design, it is a usual and prudent practice to prepare an operating plan and submit it to the appropriate state authorities for review. The plan is basically a "Standard Operating Procedure" covering all aspects of operating a landfill. Following is an outline for such an operating plan.

Management

- Personnel (staffing)
- Training
- Communications (on- and off-site)

Safety and Security

- Site access and traffic flow
- Accident and injury prevention
- Medical services
- Fire prevention and protection
- Site security
- Bird and rodent control
- Fuel storage and dispensing facilities
- Noise control

Operations

- Cell construction
- Compaction procedures
- Cover
- Revegetation
- Inclement weather operations
- Salvage operations

Maintenance

- Litter control
- Surface drainage system
- Roads
- Erosion control

Monitoring

- Inspections
- Leachate sampling and testing
- Groundwater sampling and testing
- Surface water sampling and testing
- Gas generation
- Climatological data

Records and Reports

- Waste processed
- Special wastes
- Monitoring well testing

For those required to prepare an operating plan, *Military Solid Waste Management* (Army PAM 420-47) and *Sanitary Landfill Design and Operations* (USEPA, 1972) are useful sources of information and guidance on the best landfill operating practices. Usually the engineer who designs the landfill prepares the operating plan.

Landfill Closure Plan

Another state regulatory requirement that usually requires action by the landfill design engineer and the installation (owner of the landfill) is the development of a closure plan. If required, this plan identifies the steps needed to close the facility at any point during its intended life and at the end of its intended life.

Information to be included in a closure plan includes:

- Measures to be used to prevent further dumping after the landfill is closed
- Details about the final landfill soil cover and vegetation schedule to be used
- A summary of the amount (tons or cubic yards) and types (domestic, industrial, etc.) of waste contained in each major section of the landfill.
- Proposed land-use plans for the landfill site and tentative time schedule for implementation, if any.

4 LEACHATE AND GAS PRODUCTION AND CONTROL IN NEW LANDFILLS

Wastes deposited in a landfill degrade chemically and biologically to produce solid, liquid, and gaseous products. Ferrous and other metals are oxidized; microorganisms use organic and inorganic wastes through aerobic and anaerobic synthesis. Food wastes degrade quite readily, while other materials, such as plastics, rubber, glass, and some demolition wastes, are highly resistant to decomposition. Some factors that affect degradation are the heterogeneous character of the wastes, their physical, chemical, and biological properties, the availability of oxygen and moisture within the fill, temperature, microbial populations, and types of synthesis. Solid wastes usually form a heterogeneous mass--nonuniform in size and variable in composition--that is affected by complex, difficult-to-control factors. It is not possible to accurately predict contaminant quantities and production rates. However, computer models are available to estimate total leachate production (see Chapter 5 for a description of the U.S. Army Corps of Engineers' Hydrologic Evaluation of Landfill Performance [HELP] model).

Biological activity within a landfill generally follows a predictable pattern. Solid waste initially decomposes aerobically, but as the oxygen supply is exhausted, microorganisms that do not require oxygen predominate and produce colorless, odorless, and explosive methane gas. Internal temperatures rise from 60°F to 150°F because of microbial activity. Carbon dioxide, water, and nitrate are characteristic products of aerobically decomposed wastes. Typical products of anaerobic decomposition of waste are methane, carbon dioxide, water, organic acids, nitrogen, ammonia, and sulfides of iron, manganese, and hydrogen.

Leachate Characteristics

Groundwater or infiltrating surface water moving through solid waste produces leachate. Leachate is a solution containing dissolved and finely divided solid matter and microbial waste products. It may exit the landfill at the ground surface as a spring (called a seep) or percolate through the soil and rock that underlie and surround the waste.

The composition of leachate is important in determining its potential effects on the quality of nearby surface water and groundwater. Specific contaminants carried in leachate vary, depending on solid waste composition and on the simultaneous physical, chemical, and biological activities within the fill.

The chemical and biological composition of leachate depends on the constituents in the solid waste, the age of the landfill, degree of compaction, and climatological conditions (primarily rainfall). Young landfills--generally those less than 5 years old--produce more objectionable leachate because they contain higher metal content and BOD, COD, and TOC* levels than older landfills. Table 1 lists some of the characteristics and common constituents of leachate.

Leachate can greatly affect surface water quality. Fish and other aquatic life can become so tainted as to be inedible. Aquatic animals and plants can die if high levels of toxins are present or if the oxygen in the water becomes depleted. Water unsuitable for

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*See glossary on p 77 for definitions.

Table 1

Common Leachate
Characteristics and Constituents

Parameters	Landfill-- new section	Landfill— old section	Typical permitted discharge levels
Conductivity	*3000	2500	
BOD	1800	18	45
COD	3850	246	
Ammonia-nitrogen	160	100	3
Hardness	900	290	
Iron	40.4	2.2	0.3
Sulfate	225	100	50

*All values in mg/L except conductivity (micromhos).
Note: age difference in old and new > 20 years.

most aquatic life is usually not acceptable for aquatic sports or usable as a source of either drinking or industrial process water.

When leachate permeates an aquifer, water can become unfit for human and domestic animal consumption. Reports of illness in people who unknowingly drank water from contaminated wells have become all too common. While most of these incidents stemmed from the disposal of liquid chemical wastes, comparable effects can result from leachate-contaminated groundwater. Once contaminated, underground waters are usually very difficult and very expensive to restore to usable condition. Chapter 5 discusses some of the technologies for correcting groundwater contamination at Army installations.

Leachate Control Methodologies

When designing new landfills, it is not just prudent, but mandatory in most states to provide for leachate control. The fundamental approach to control is first to confine leachate to the limits of the landfill, and then to collect and dispose of it safely.

The following is a review of various technologies that an Army installation could use to collect, contain, and treat leachate.

Leachate Collection

Use of collection techniques assumes that a relatively impermeable soil or artificial liner is in place to confine the leachate to the disposal site. The most common type of collection system is a gravity system with sand, gravel, and/or perforated pipes that route the leachate to a collection point (see Figure 1).

Pipe location and placement are critical to leachate collection system performance. Crushing or displacement of pipe caused by equipment loading and/or differential settling are well-recognized problems. A pipe is best protected when it is

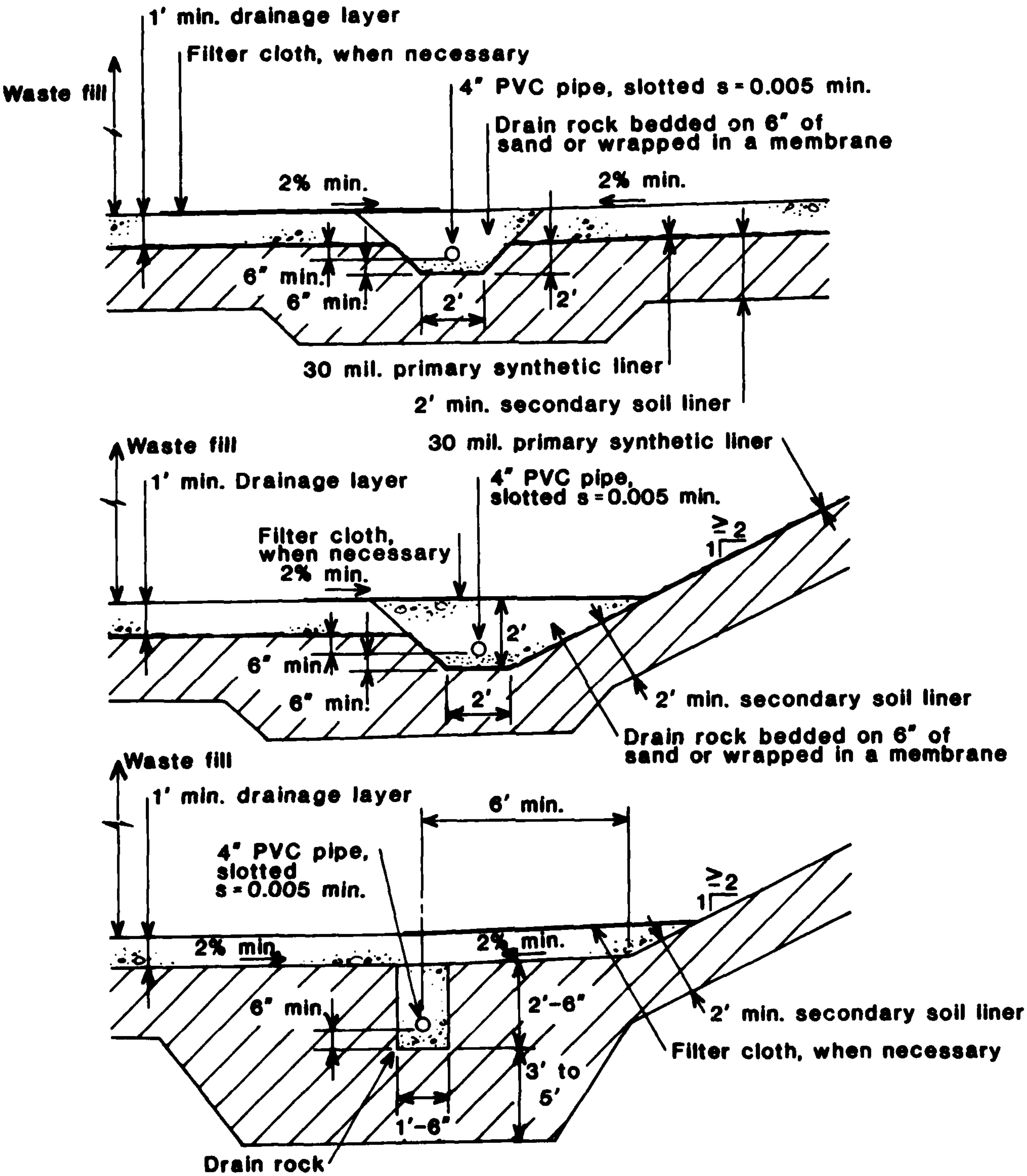


Figure 1. **Typical leachate collection drains.** (From Technical Manual [TM] 5-814-7, *Hazardous Waste Land Disposal/Land Treatment Facilities* [Department of the Army, November 1984].)

placed in a trench, with careful consideration given to loading conditions and proper bedding. The trench provides added protection for the pipe, especially during placement of the first lift of waste when the pipe is most susceptible to crushing.

Design redundancy is important to minimize the effect of any failure. The system should be able to remove liquid from any point in the facility by more than one pathway. One of the primary ways to provide redundancy is to design collection laterals so that drainage requirements can be met by the gravel layer alone if flow through the pipe is restricted. In addition, laterals should be spaced so that if one lateral is totally blocked, liquid can be removed through an adjacent lateral.

One of the most important considerations for preventing failure is designing the system to facilitate inspection and maintenance. There should be access to all parts of the system. This includes the placement of manholes and cleanouts so that maintenance equipment can reach any length of pipe. The design should consider minimum pipe sizes, distance between access points, and maximum angles negotiable by cleaning equipment.

Finally, leachate collection systems should be designed to avoid clogging. For example, sedimentation can be avoided by properly selecting grain size distribution in the filter material to exclude solids, and by providing minimum slopes to maintain flow velocity during leachate collection so that solids cannot settle out. Maintaining flow velocity will also help prevent buildup of biological and chemical materials that tend to block flow.

Lining Technologies

A variety of liner types have been installed at landfill sites to prevent the migration of leachate constituents to adjacent groundwater supplies. Four types of liners have been used: (1) natural soil liners, (2) membrane liners, (3) asphalt/tar type liners, and (4) treated soil liners.

Natural Soil Liners

Since a major function of the liner material is to minimize leachate movement, only highly impermeable soils are acceptable as liner materials. Required permeability rates are about 10^{-7} cm/sec. Where the in-place natural soil cannot meet this criterion, an impermeable barrier may be constructed by placing a 2-ft compacted impermeable soil type along the base and sides of the landfill area. Generally, clays are the most commonly used natural soil liner material.

Membrane Liners

Membrane materials used to line sanitary landfills include polyethylene, polyvinyl chloride, butyl rubber, Hypalon (a Dupont trademark), ethylene propylene diene monomer, and chlorinated polyethylene. Membrane thicknesses range from 10 to 60 mils, with 20 to 30 mils being the most commonly used. Table 2 summarizes the advantages and disadvantages of the various membrane liner materials. Generally, polyvinyl chloride and polyethylene are the most commonly used liner materials.

Basic liner materials can be strengthened by using a sandwich-type construction, with a reinforcing fabric laminated between layers of the liner material. Typical reinforcing "scrim" materials include nylon, dacron, polypropylene, and fiberglass fabrics. The reinforced liner material provides better puncture resistance and overall

Table 2

Utility of Polymeric Materials as Liner Materials

Liner material	Advantages	Disadvantages
Polyethylene	Low cost Chemical resistance Tensile strength Low-temperature handling	Weatherability Puncture resistance Unexposable
Polyvinyl chloride	Range of manufactured properties available Chemical resistance	Some formulations subject to biological degradation Low-temperature handling Unexposable
Butyl rubber	Low permeability Exposable	Lack of chemical resistance to hydrocarbons and solvents Splicing difficulty
Hypalon	Puncture resistance Low-temperature handling Chemical resistance Exposable	Cost Tensile strength
Ethylene propylene diene monomer	Exposable Low-temperature handling	Lack of chemical resistance to hydrocarbons and solvents
Chlorinated polyethylene	Tensile strength Elongation strength	Chemical resistance

loading capacity than the liner material alone. Specific disadvantages include less flexibility, elongation followed by rupture, and greater cost.

Liner installation requires a number of specialized construction techniques. The base on which the liner will be placed must be even and free of objects that could rupture it. Six inches of graded sand are commonly used as a liner base.

Actual liner installation requires joining large membrane sheets over the landfill base and the use of reinforcement patches around openings for vents, sampling wells, collection pipes, etc. A number of adhesives and solvents are used to construct these field splices. Manufacturer instructions must be followed carefully to ensure the liner's structural integrity.

Once the liner installation is complete, continued emphasis must also be placed on maintaining liner integrity. The most common approach is to provide a 2-ft graded sand or soil layer over the liner to prevent waste materials from rupturing the liner and to permit operation of landfill equipment on the liner surface.

Asphalt/Tar Type Liners

A variety of construction methods have been used to install asphalt sanitary fill liners. Among the options available are:

1. A hot sprayed asphalt up to 3/4 in. thick at an application rate of about 2 gal/sq yd

2. A 2-in.-thick hot asphalt mix with a tar emulsion sealer and 6 in. of sand cover

3. A 2-in.-thick cold-mix asphalt pavement with sealer coats of emulsified asphalt and tar emulsion at application rates of 1/4 gal/sq yd

4. A 3-in.-thick tar cement pavement using tar binder (instead of asphalt binder which is less dense than water) and a hot-tar spray sealer

5. An asphalt emulsion sprayed over a polypropylene fabric base.

Installation of asphalt liners requires two specialized types of equipment. Asphalt pavements 2 to 3 in. thick are placed, using conventional roadway paving equipment. Sealer coats are then applied using a distributor truck with spray bar equipment.

Treated Soil Liners

This type of liner is usually constructed by adding a limited variety of naturally occurring clay minerals (sold commercially as bentonite and volclay) to the soil base. The clay material (montmorillonite), effectively seals the soil spaces and decreases effective permeability rates. Construction of the liner requires disking the admixture about 6 in. into the soil at application rates ranging from 10 to 20 lbs/sq yd. Flat-steel or rubber-tired rollers are used for final compaction.

A second type of treated soil liner can be provided by mixing Portland cement at application rates of 3 to 20 percent by weight to the natural soil. The procedure involves pulverizing the soil, thoroughly mixing the soil and cement additive, applying water, compacting, and wet curing. For this type of liner, sandy and silty soils or soils with high organic content are preferable to clays, since lower cement application rates are required.

Leachate Treatment

Once leachate is collected, there are three options. The first requires using a treatment process to remove waste contaminants. A variety of biological and physical/chemical processes have had limited use to date. Biological processes used include aerated lagoons, complete-mix anaerobic filters, and activated sludge. Physical/chemical treatment methods include carbon adsorption, chemical precipitation, ultrafiltration, reverse osmosis, ion exchange, and ozonation. Generally, younger leachates are amenable to treatment by biological methods while physical/chemical processes are useful for treating of older, more stabilized leachates, or as a polishing process for biologically pretreated leachates.

The second option for leachate disposal is use of the treatment process in a wastewater treatment plant. Generally, where a secondary-type biological treatment plant is available, a leachate to wastewater ratio of up to 1-to-20 will produce acceptable treatment without upsetting the biological process.

A third option involves collecting and recycling the leachate through the waste constituents. The advantages of the procedure include rapid development of the anaerobic bacterial population of methane-formers that provide most of the decomposition. This causes the organic pollutant constituents to stabilize much more rapidly and the production of high-strength leachates over a shorter period of time, thus resulting in decreased potential of environmental degradation. Recirculation with

artificial pH control to about 7.0 (to maximize optimum anaerobic decomposition conditions) and sludge seeding (to establish an anaerobic microbial population), causes much more rapid development of the required bacterial populations; this results in more rapid organic stabilization. However, many states forbid recycling leachate because it increases the hydraulic loading in the landfill and raises the probability for groundwater contamination.

Leachate Monitoring

Due to the potential for adverse environmental and public health impacts, state regulations may require a sampling and testing program to monitor the effectiveness of a landfill liner and leachate collection system in preventing groundwater contamination. The usual procedure is to install monitoring wells from which water samples are periodically taken and analyzed.

Monitoring wells ranging from 2 to 6 in. in diameter should be established up-gradient and down-gradient from the landfill site and should be located to penetrate major water bearing aquifers. At least four wells are generally recommended. Figure 2 presents a typical monitoring well schematic. Monitoring frequencies depend on well type, groundwater flow characteristics, trends in accumulated monitoring data, and climatological considerations. Generally, periodic overview monitoring should be done at least quarterly. More extensive groundwater sampling should occur at least once yearly. Overview monitoring should include testing for pH, COD, specific conductance, chloride, and alkalinity. Full-scale testing should include pH, oxidation-reduction potential, specific conductance, COD, TOC, volatile acids, chloride, sulfate, phosphate, alkalinity, nitrate, heavy metals, and any other contaminant potentially present due to specific waste types. Appendix A lists priority pollutants that should be checked when hazardous waste contamination is suspected.

The effectiveness of a monitoring effort is highly dependent on the use of proper sampling techniques and sample preservation procedures. These tasks and the actual testing should be performed only by experienced laboratory technicians because incorrect measurements can be costly in terms of lost time and money and can cause planning errors.

Decomposition Gas Characteristics

Gas is produced naturally when solid wastes decompose. The amount of gas generated in a landfill and its composition depend on the types of solid waste that are buried. A waste with a large fraction of easily degradable organic material will produce more gas than one that consists largely of ash and construction debris. The rate of gas production is governed solely by the rate of microbial decomposition occurring in the solid waste. When decomposition ceases, gas production also ends.

A major product of landfill decomposition processes is a gaseous mixture consisting mostly of methane and carbon dioxide, with small quantities of nitrogen, oxygen, and hydrogen sulfide. The amount of gas production depends primarily on the amount and type of organic materials, permeability and thickness of soil cover, temperature variation, density, and moisture content. Migrating radially by diffusion and convective flow, the methane can collect in explosive concentrations (5 to 15 percent in the presence of oxygen) in adjacent sewer lines or in buildings near landfills. A common estimate used to predict the potential extent of methane migration is 10 times the

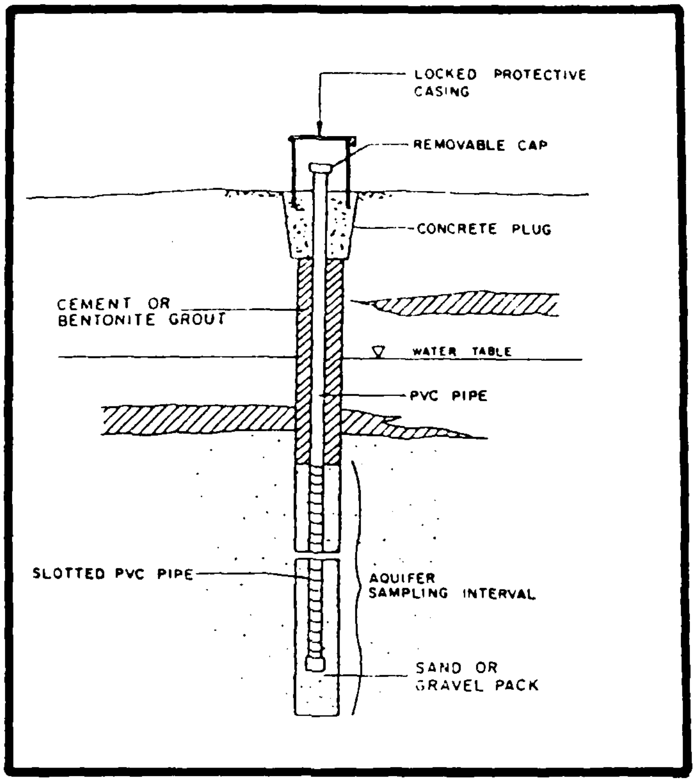


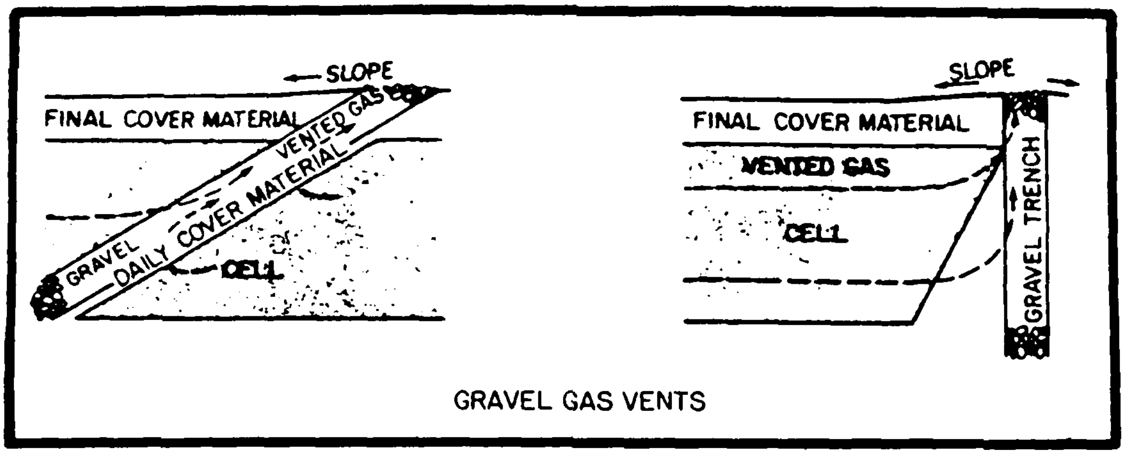
Figure 2. Typical monitoring well. (From TM 5-814-7, *Hazardous Waste Land Disposal/Land Treatment Facilities* [Department of the Army, November 1984].)

vertical waste depth. This value is only a general estimate, since site-specific subsurface conditions, such as an impermeable liner and porous substrata, can result in methane migration of hundreds of feet. A typical sign of the subsurface presence of methane gas is the death or unhealthy appearance of adjacent vegetation. Methane can suffocate a variety of plant species by blocking oxygen from the root zone.

In some cases, natural soil, hydrologic, and geologic site conditions may combine with a permeable landfill cover to direct the gas harmlessly into the atmosphere. Where these conditions do not exist, gas venting systems must be installed that vent decompositon gases safely into the atmosphere.

Gas movement can be controlled in several ways. Lateral movement can be curtailed with impermeable side barriers made of a variety of materials, including natural clays, bentonite or volclay slurries, or synthetic membrane liners. Typical construction consists of a 2- to 3-ft-wide ditch excavation to below maximum waste depth. The ditch is then filled with compacted clay or the selected slurry material. This approach requires gas venting through the cover material.

Permeable materials may also be used to control gas movement. Gravel vents or gravel-filled trenches or barriers collect migrating gas and permit direct venting into the atmosphere. To be effective, these vents must extend below landfill depth, and must be kept well-drained and free of soil and vegetation. This method, as well as the installation of vertical vent pipes, can be used where an impermeable cover is employed to reduce leachate generation. Figure 3 shows typical gas-venting techniques.



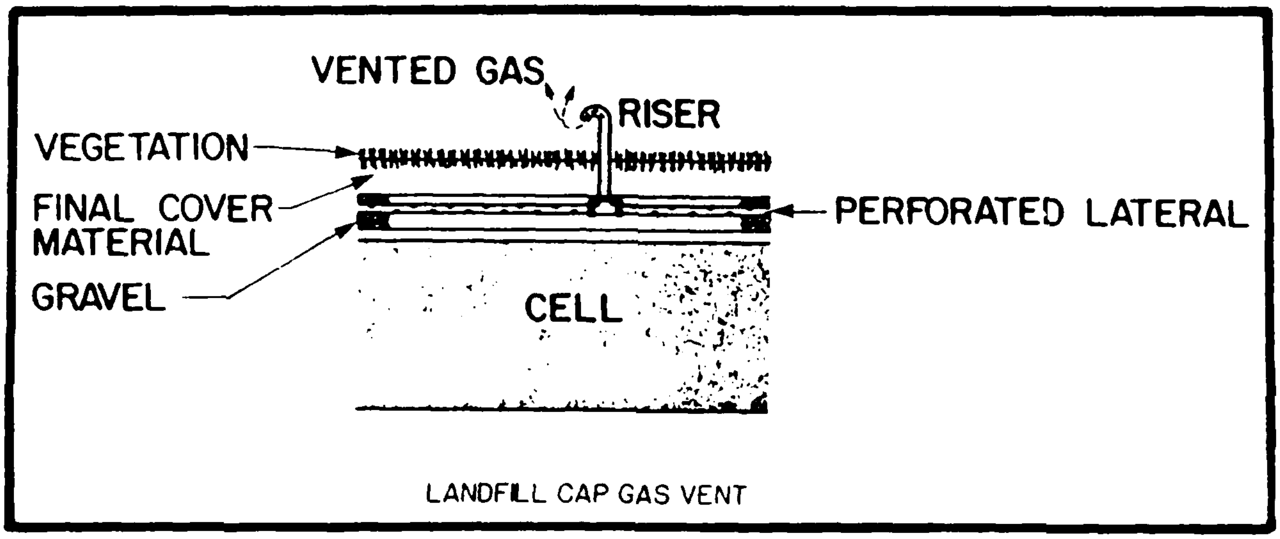


Figure 3. **Gas venting techniques.** (From R. A. Shaffer, et al., *Landfill Gas Control at Military Installations*, Technical Report N-173/ ADA140190 [USA-CERL, 1984].)

Gas Monitoring

Potential environmental and public health effects from methane can be of sufficient concern that state regulatory agencies impose a monitoring requirement on the landfill owner. Monitoring is generally conducted at the periphery of the landfill site, selecting possible migration routes that could produce a safety hazard (e.g., methane collection in an adjacent building). Portable gas detectors equipped with hand-driven probes are often used for intital investigations. However, a permanent gas monitoring well similar to that shown in Figure 4 is installed once the presence of gas has been confirmed and long-term monitoring is to be initiated. Monitoring frequency is usually site-specific, but quarterly or even monthly testing is common practice.

Several Army agencies can perform gas monitoring or can provide consultation on establishing an in-house program. Table 3 identifies available sources of information and assistance.

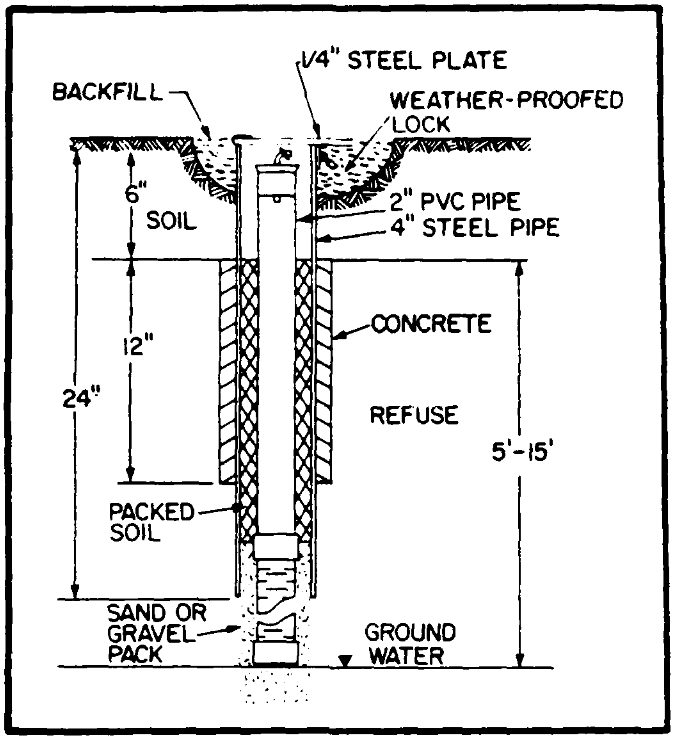


Figure 4. **Gas monitoring well.** (From R. A. Shaffer, et al., *Landfill Gas Control at Military Installations*, Technical Report N-173/ ADA140190 [USA-CERL, 1984].)

Table 3

Sources of Information and Assistance

ITEMS	AGENCIES: EPA REGIONAL OFFICE	US GEOLOGICAL SURVEY DISTRICT	US FISH & WILDLIFE REGION	STATE EPA	STATE GEOLOGICAL SURVEY	STATE WATER MANAGEMENT OFFICE	STATE FISH & GAME OFFICE	OCE	CERL	AEHA	WES	USATHAMA	OCE HUNTSVILLE ENGR DIVISION	CORPS OF ENGINEER DISTRICT
REGULATORY REQUIREMENTS														
LANDFILL SITING CRITERIA	X			O				X	X	O	X			
LANDFILL DESIGN & OPERATING CRITERIA	X			O				X	X	O	X			
THREATENED/ENDANGERED SPECIES			X				O		X					
LEACHATE CONTROL REQM'TS				O					X	X				
GAS CONTROL REQM'TS				O										
LANDFILL PERMITS				O										
NPDES PERMITS	X			O										

X SOURCE

O PRIMARY SOURCE

Table 3 (Cont'd)

ITEMS	AGENCIES													
	EPA REGIONAL OFFICE	US GEOLOGICAL SURVEY DISTRICT	US FISH & WILDLIFE REGION	STATE EPA	STATE GEOLOGICAL SURVEY	STATE WATER MANAGEMENT OFFICE	STATE FISH & GAME OFFICE	OCE	CERL	AEHA	WES	USATHAMA	OCE HUNTSVILLE ENGR DIVISION	CORPS OF ENGINEER DISTRICT
SOURCE DATA & CONSULTATION														
SITE GEOLOGIC DATA		X			O									
SITE SOIL DATA		X			O				X				O	
LANDFILL GROUNDWATER DATA		X			X	O				O			X	
LANDFILL ENGINEERING								X	O		X		X	
LANDFILL BEST MANAGEMENT PROCEDURES								X	O	O	X		X	
NEW MONITORING WELL LOCATION				X	X				O	O	O		X	
LEACHATE DETECTION & CONTROL TECHNOLOGIES				X					O	O	O		X	
GAS DETECTION & CONTROL TECHNOLOGIES				X					O		X		X	
WATER QUALITY STANDARDS				O		O			X	O	X		X	
LEACHATE & GAS PROBLEM ANALYSIS								X	O	O	O	O	X	
ON-SITE INVESTIGATION														
GROUND/SURFACE WATER SAMPLING & ANALYSIS									X	X		X		
MONITORING WELL DRILLING & LOGING									X	X	X	X		
DETECTION & GAS MONITORING									X		X	X		
SOIL SAMPLING & ANALYSIS					X				X	X		X		X
FISH & WILDLIFE SURVEY							X		X	X				
WILDLIFE POST MORTEM							X		X	X				
RESISTIVITY SURVEY											X	X		X
ELECTROMAGNETIC SURVEY											X	X		X
ENGINEERING ASSISTANCE														
LANDFILL DESIGN									X	X	X		X	X
LANDFILL PERMIT APPLICATION PREPARATION									X	X	X		X	
LEACHATE CONTAINMENT COLLECTION SYSTEM									X	X	X		X	X
LEACHATE TREATMENT PROCESSES									X			X		X
GAS CONTROL SYSTEMS									X			X		X
GROUNDWATER RENOVATION TECHNOLOGIES									X			X	X	X

5 LEACHATE PRODUCTION AND CONTROL IN OLD LANDFILLS

The probability of incurring environmental damage from leachate production is greatest with old (closed) sanitary landfills. This is primarily because careful siting and operating procedures for landfills did not exist until 1972, when USEPA published its first regulation on land disposal of solid wastes (40 CFR 241). Furthermore, the possibility that buried solid waste could adversely affect surface and groundwaters was so little understood 20 to 30 years ago that landfilling operations were often haphazard.

Landfill sites at Army installations were often placed in remote locations on land that was available because it was not particularly suited for training. Sometimes, sites were located in low-lying areas or ravines, with little attention given to the location of the groundwater table. Also, no attention was given to restricting the types of wastes being buried. Compacting waste to achieve high density and carefully selecting soil that would effectively seal the waste were not considered important. All of these factors contributed to production of the leachate that now migrates off-site and damages the nearby environment.

Evidence of Leachate Problems

Obvious signs of leachate production are small springs, called seeps, of discolored, malodorous liquid along the lower edges of many landfills. Often associated with seeps are other signs, such as vegetation stress or the total destruction of most lifeforms in the surrounding area. In nearby surface water, particularly a pond or marshy areas, discolored water, the presence of dead fish, and stressed aquatic vegetation are often signs of possible leachate migration.

Leachate contamination of groundwater is less obvious. However, it can be suspected when complaints of bad-tasting water or unexplained illness are reported by wellwater users in the surrounding area.

The presence of leachate should be verified by analyzing the chemical composition of samples collected from seeps, contaminated surface water, or wellwater. Most well-equipped commercial laboratories can perform a chemical analysis. Several Army agencies also have this capability: AEHA, Ground Water and Solid Waste Branch; U.S. Army Construction Engineering Research Laboratory (USA-CERL), Environmental Division; USATHAMA. These organizations can perform the tests, have experience in interpreting test results, and can often recommend possible follow-on action. (Chapter 6 provides addresses and telephone numbers for points of contact at these agencies.)

Confirmation of the presence of leachate, the extent of its migration, and the presence of toxic substances in groundwater generally require that a number of monitoring wells be installed and a water sampling and testing program instituted. Table 3 lists several Army agencies that can perform this work.

Before any drilling, a great deal of information about the landfill site must be collected and analyzed. Such information includes the landfill boundaries; subsurface geology, soil, and groundwater data; and age and contents of the landfill. A possible source of this type of historical data is the Phase I and Phase II, Installation Restoration (IR) Reports produced by the USATHAMA (see Chapter 6). If such reports have not been prepared for a specific site, USATHAMA, AEHA, or the installation itself may have to perform an investigation to obtain the information.

Investigative Landfill Surveys

In situations where historical data are inadequate, the landfill investigator must rely on resources such as maps, aerial photos and record files, or information from long-term employees who can be questioned about a landfill site. However, more elaborate scientific measures may still be needed to obtain the necessary information.

A variety of geophysical methods are available to obtain subsurface information about a landfill site. Some of the more widely used procedures listed below involve the use of sophisticated equipment and require highly trained personnel to interpret the data. Since these skills are not normally found among installation personnel, the agencies listed in Table 3 that have or can provide this capability should be contacted.

Electrical "E" Logs

This process involves measuring electrical properties of soils and geologic formations in uncased boreholes. The data collected will yield information the on potential of strata to transport water, the occurrence of water, and general water quality. The cost may vary, depending on hole depth and condition.

Electrical Resistivity Survey

This method employs vertical electrical soundings (VES) that transmit electrical currents into the ground. The VES may be considered an electrical "drill hole" which, in effect, defines subsurface strata. The method allows rapid evaluation of subsurface conditions to great depth at minimum cost.

Magnetometer Survey

This method measures the magnetic intensity of rock and strata for defining geologic structure. Magnetometer surveys can cover large areas at minimum costs. These capabilities are being used to determine the location of buried drums and their relative position (i.e., upright, on one side, at a skew angle).

Electromagnetic Survey

This method measures the apparent conductivity of the ground using an audio-frequency transmitter and receiver. The procedure provides the skilled user general information about the character of subsurface strata.

Groundwater Flow Measurements

This procedure involves inserting highly sensitive meters into wells. Both groundwater flow rates and direction can be measured.

Leachate Production Estimates

Pre- and post-closure leachate production and flow from landfills may be estimated by employing the HELP model. The model can be effectively used to estimate total leachate flow produced by and escaping from landfills. The HELP model was specifically designed for hazardous waste sites where liners and leachate collection systems are used. However, the model can also be used for an open landfill configuration in which leachate control was not previously considered.

The model employs climatologic, soil, and other design data to predict the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and horizontal drainage from the base of the landfill to a collection system. Furthermore, several combinations of vegetation types, soil cover material, different waste cells, varying drainage arrangements, and impermeable barrier soils may be modeled.

A copy of the *HELP Model Users Manual* may be obtained from the Solid and Hazardous Waste Research Division, Hazardous Waste Engineering Laboratory, Cincinnati, OH 45268 or from the U.S. Army Waterways Experiment Station (WES), Vicksburg, MS 39180. (Note: this model is complex and requires some knowledge of hydrogeology. Thus, it is suggested that prospective users contact WES to conduct the study.)

Corrective Techniques/Technologies

Measures required to correct leachate contamination can range from simple to complex, and the cost can vary from modest to nearly prohibitive. Generally, it is much easier and less costly to control surface leachate releases than it is to decontaminate groundwater supplies.

Selecting specific corrective measures and deciding when they should be taken can often be difficult. One factor affecting the decision process is identification of potential receptors of a pollutant release, such as a drinking water aquifer or surface water designated as a public water supply. If there are no receptors, extensive corrective measures would probably not be necessary. However, if toxic substances are entering surface or subsurface drinking water supplies, prompt action should be taken. In the latter situations, it will usually be easier and cheaper in the long run to correct a leachate contamination situation in its early stages rather than allow the problem to get worse.

Leachate Releases Not Affecting Groundwater

Minor and intermittent leachate seeps often indicate a faulty landfill cover. Here, corrective action may only involve placing additional soil cover. If a steady flow is noted, the integrity of the landfill cover should be examined carefully. Subsidence may have occurred, causing surface water to collect and percolate into the refuse and build up enough to produce flow. This condition could also occur because of defective surface water run-on and run-off controls or because the soil cover was too permeable. Filling low areas and reshaping the surface may correct such problems; however, it may be necessary to recap the entire fill area with less permeable material. This can be done at a relatively low cost if soil with adequate clay content is available nearby on the installation. (Supporting Corps of Engineers District Offices can perform soil analyses.)

An alternative that is much more expensive is to install a membrane cover on a landfill. This type of work requires special equipment to handle large rolls of membrane, produce waterproof seams, and properly anchor the edges. Therefore, it is wise to use experienced contractors to install the membrane, emplace a protective topsoil over the entire surface, and revegetate the area. For more information about landfill membrane liners and covers, see USA-CERL Technical Report N-183.

When a landfill continuously releases leachate, it may be appropriate to install a drain or sump to accelerate the removal of accumulated liquid and thereby remove any

potential environmental hazard. Slotted polyvinyl chloride (PVC) pipe or gravel drains can be installed for this purpose. Leachate should then be collected in a membrane-lined lagoon, where it may be possible to treat it in place. Alternatively, the collected leachate may be pumped out periodically and transported to a sewage treatment plant for disposal. Where gravity flow to a collection lagoon is not possible, sumps may be built near the landfill perimeter, using an earth auger. Collected leachate can then be pumped from the site periodically. USA-CERL Technical Report N-155 outlines various options for treating leachate to permit safe disposal.

Leachate Releases Affecting Groundwater

The most difficult leachate control problem is when hazardous pollutants have entered an aquifer used for drinking water and they exceed prescribed health standards. Here, controls can be applied to either the leachate source, the aquifer, or both. The choice will be based on the specific circumstances.

Minor to moderate pollutant levels in groundwater may be adequately reduced by decreasing the quantity of surface water percolating through the landfill. This may be done by repairing the existing landfill soil cover or by installing new cover material and revegetating the area. Cutting down the volume of leachate released into the groundwater in this manner may lower pollutant levels. Normal groundwater flow could thereby dilute pollutant concentrations to acceptable levels.

When wastes are buried below the water table, major construction is often required to keep groundwater out of the landfill. Possible measures for controlling groundwater are to divert or block its flow; this can be done by installing clay barriers with underdrainage systems, installing a slurry trench, injecting a grout curtain, or driving sheet-piling up the groundwater gradient from the landfill. Other more expensive options that should be considered in only the most difficult situations are bottom-sealing the landfill by grout injection, installing well points to lower the water table below the base of the buried waste, and completely removing and reburying waste at an alternative authorized site. Figure 5 illustrates technologies used to control groundwater movement and leachate migration.

Subsurface Leachate Migration

Many of the same techniques and technologies used to block groundwater inflow into a sanitary landfill can also be used to block outflow from reaching a well field or nearby surface waters. The use of slurry trenches to keep underground plumes of pollutants from hazardous waste dumps from reaching critical aquifers is so commonplace today that specialty firms perform this type of construction. However, to properly locate and design a slurry wall, grout curtain, or other barrier system, an extensive hydrogeological investigation must first be completed to determine the flow rate, depth, and direction of pollutant movement. One of the first Army installations to use bentonite slurry walls was Rocky Mountain Arsenal. The walls were installed to prevent liquid chemical wastes held in storage lagoons from seeping into an aquifer used to water livestock on farms adjacent to the Arsenal. The Corps of Engineers performed the investigative work and follow-on construction for this job.

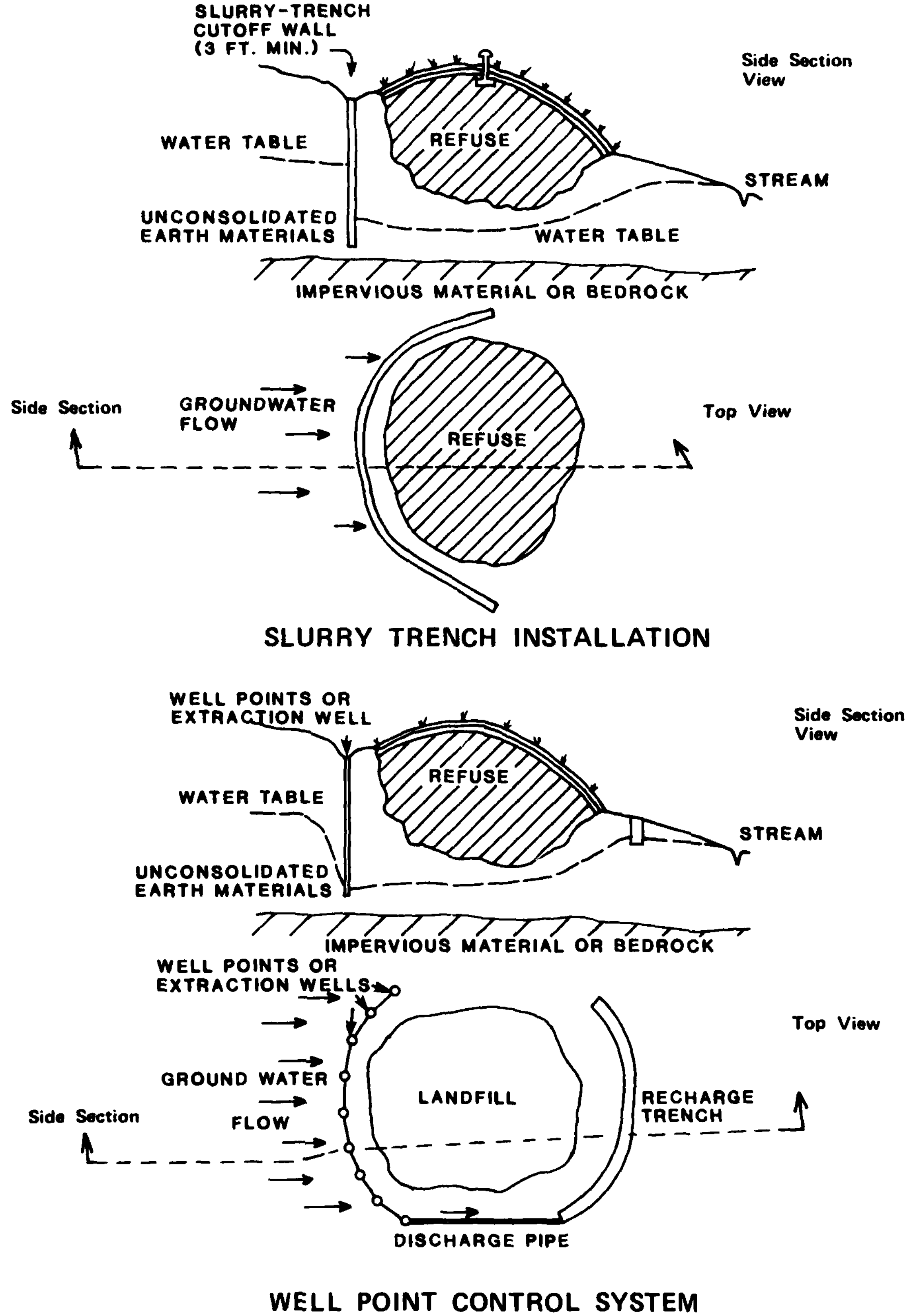


Figure 5. Groundwater control technologies. (From W. J. Mikucki, et al., *Control and Treatment of Leachate at Military Installations*, Technical Report N-97/ADA097935 [USA-CERL, 1981].)

Leachate Treatment Options

Landfill leachate has much higher concentrations of toxic contaminants than raw domestic sewage. However, many of the same biological and chemical treatment processes used to treat sanitary sewage can be used for leachate. USA-CERL Technical Report N-155 provides a comprehensive discussion of the various leachate treatment processes.

Compared to municipal landfills, the typical Army sanitary landfill is relatively small; consequently the small volume of leachate would not normally warrant installation of a separate treatment facility. In most cases, collected leachate can be added to the inflow of a sewage treatment plant, if the amount of high-strength leachate does not exceed 5 percent of the plant flow.

Leachate Problem Checklist

Appendix B contains a checklist designed to help Army installations identify, characterize, quantify, and correct a leachate problem. The user should proceed sequentially through the list, entering answers to the questions about each factor in the appropriate comment block.

6 SOURCES OF TECHNICAL INFORMATION AND ASSISTANCE

This chapter contains information about Federal, state, and Army agencies that can provide information and technical assistance on designing and operating new sanitary landfills and on siting investigation procedures and engineering that may be required to correct leachate pollution and methane gas hazards from old landfills. Table 3 identifies specific agencies that are potential sources of assistance on the various aspects of solid waste disposal. Those identified by an "O" are considered the primary sources for Army installations. Items of possible interest are identified under four major headings: regulatory requirements, source data and consultation, on-site investigation, and engineering assistance. Complementing the table is the information provided below about the capabilities of the agencies/organizations listed, the mailing address, and telephone numbers of those offices where assistance may be obtained.

Federal Agencies

Regional USEPA Offices

USEPA regional offices are responsible for implementing and enforcing USEPA programs in states within their jurisdictions (Figure 6). Questions related to the impact of Federal solid waste regulations on military installations should be referred to the Federal Facilities Coordinator or to the Solid Waste Management Office, whose addresses and telephone numbers are provided in the directory on p 37.

U.S. Geological Survey

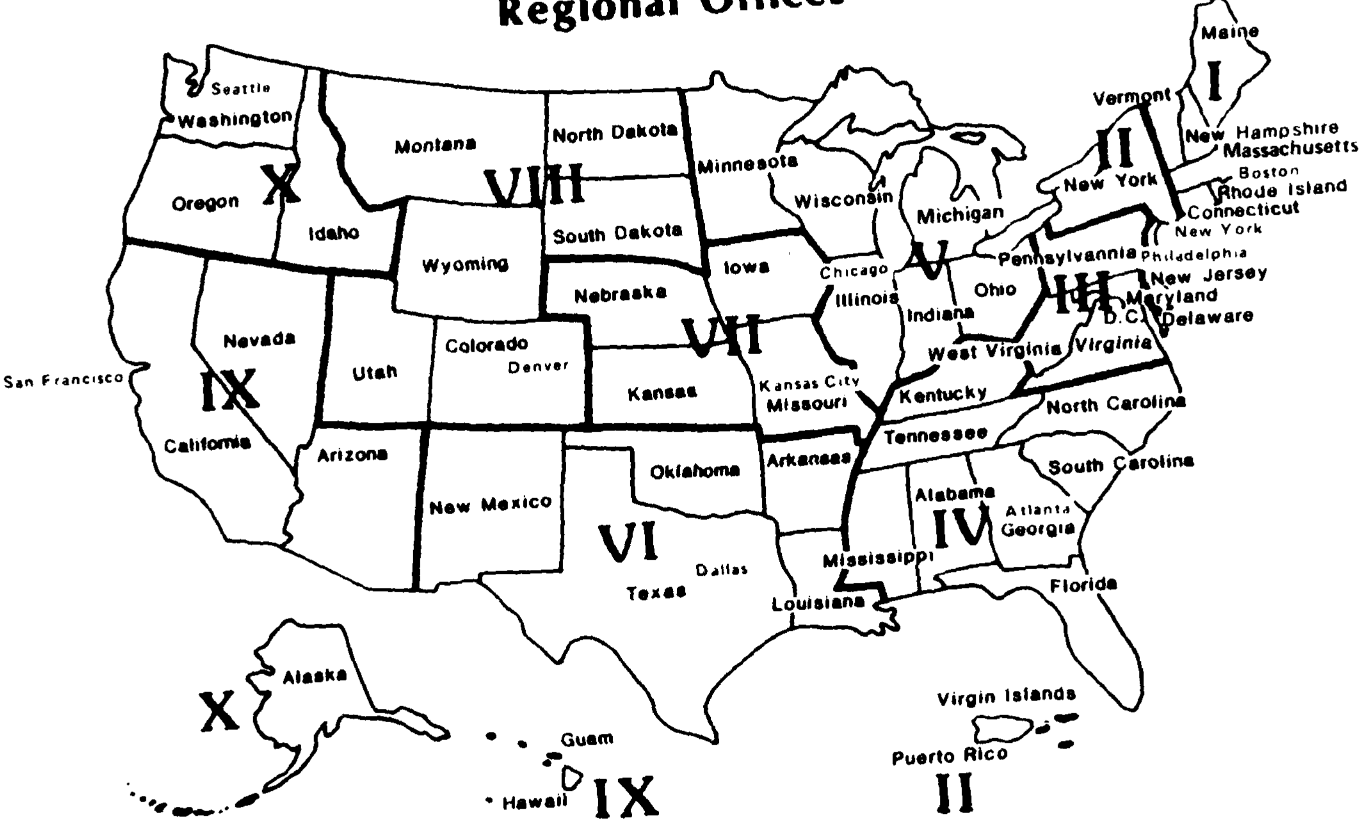
The Survey is divided into five organizational units with interrelated functions: the Topographic Division, the Geologic Division, the Water Resources Division, the Conservation Division, and the Land Information and Analysis Office. The Water Resources Division determines the source quantity, quality, distribution, movement, and availability of both surface- and groundwater. This information is invaluable for predicting the environmental consequences of alternative plans for developing water resources. The directory on pp 38-42 provides the addresses and telephone numbers of the Water Resources Division in each state's U.S. Geological Survey District Office.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service provides leadership for protecting and improving land and water environments (habitat protection). It also designates endangered species under the Endangered Species Act.

The Service is a valuable source of data on fish, wildlife, and habitat preservation. It should also be contacted for information when the Army must evaluate impacts and impact mitigation procedures for an activity or action to be carried out on or adjacent to land that could be considered environmentally critical in terms of natural habitat. The directory on p 43 gives the addresses and telephone numbers of the U.S. Fish and Wildlife Services regional offices.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Regional Offices



REGIONS

IV...Alabama
X...Alaska
IX...Arizona
VI...Arkansas
IV...Atlanta
I...Boston
IX...California
V...Chicago
VIII...Colorado
I...Connecticut
VI...Dallas
III...Delaware
VIII...Denver
III...D.C.
IV...Florida
IV...Georgia
IX...Hawaii
X...Idaho
V...Illinois
V...Indiana
VII...Iowa
VII...Kansas
VII...Kansas City
IV...Kentucky
VI...Louisiana
I...Maine
III...Maryland
I...Massachusetts
V...Michigan
V...Minnesota
IV...Mississippi
VII...Missouri
VIII...Montana
VII...Nebraska
IX...Nevada
I...New Hampshire
II...New Jersey
VI...New Mexico
II...New York
II...New York City
IV...North Carolina
VIII...North Dakota
V...Ohio
VI...Oklahoma
X...Oregon
III...Pennsylvania
III...Philadelphia
I...Rhode Island
IX...San Francisco
X...Seattle
IV...South Carolina
VIII...South Dakota
IV...Tennessee
IV...Texas
VIII...Utah
I...Vermont
III...Virginia
X...Washington
III...West Virginia
V...Wisconsin
VIII...Wyoming
IX...American Samoa
IX...Guam
II...Puerto Rico
II...Virgin Islands

Figure 6. Regional USEPA offices.

DIRECTORY: REGIONAL OFFICES, U.S. ENVIRONMENTAL PROTECTION AGENCY

Region (states covered)	Address	Federal Facilities Coordinator	Solid Waste Management Office
I (CT, MA, ME, NH, RI, VT)	USEPA, Region I J.F. Kennedy Fed. Bldg. Boston, MA 02203	(617) 223-5610	(617) 223-5186
II (NJ, NY, PR, VI)	USEPA, Region II 26 Federal Plaza New York, NY 10278	(212) 264-1892	(212) 264-0504
III (DE, MD, PA, VA, WV, DC)	USEPA, Region III Curtis Building 6th and Walnut Streets Philadelphia, PA 19107	(215) 597-4799	(215) 597-0980
IV (AL, FL, GA, KY, MS, NC, SC, TN)	USEPA, Region IV 345 Courtland Street Atlanta, GA 30365	(404) 881-3776	(404) 881-3454
V (IL, IN, MI, MN, OH, WI)	USEPA, Region V 230 S. Dearborn Street Chicago, IL 60640	(312) 353-2114	(312) 353-7435
VI (AR, LA, NM, TX, OK)	USEPA, Region VI 1201 Elm Street Dallas, TX 75270	(214) 767-9930	(214) 767-2730
VII (IA, KS, MO, NE)	USEPA, Region VII 725 Minnesota Avenue Kansas City, MO 66101	(913) 374-5593	(913) 236-2850
VIII (CO, MT, ND, SD, UT, WY)	USEPA, Region VIII 1 Denver Place 999 18th Street Denver, CO 80202-2413	(303) 837-3826	(303) 293-1720
IX (AZ, CA, HI, NV GU)	USEPA, Region IX 215 Freemont Street San Francisco, CA 94105	(415) 974-8290	(415) 974-8119
X (AK, ID, OR, WA)	USEPA, Region X 1200 Sixth Avenue Seattle, WA 98101	(206) 442-1756	(206) 442-2782

DIRECTORY: DISTRICT OFFICES OF THE U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION

ALABAMA

University of Alabama
Oil & Gas Building - Room 202
P.O. Box V
Tuscaloosa, AL 35486

(205) 752-8104

ALASKA

218 E. Street
Anchorage, AK 99501

(907) 271-4138

ARIZONA

Federal Building
301 W. Congress Street
Tucson, AZ 85701

(501) 378-6391

CALIFORNIA

855 Oak Grove Avenue
Menlo Park, CA 94025

(415) 323-8111

COLORADO

Building 53
Denver Federal Center
Lakewood, CO 80225

(303) 234-5092

CONNECTICUT

135 High Street - Room 235
Hartford, CT 06103

(203) 244-2528

DELAWARE

Subdistrict - District Office/MD
Federal Building - Room 1201
Dover, DE 19901

(302) 734-2506

FLORIDA

325 John Knox Road - Suite F-240
Tallahassee, FL 32303

(904) 386-1118

GEORGIA

Suite B
Peach Tree, Industrial Boulevard
Doraville, GA 30360

(404) 221-4858

GUAM

Subdistrict
U.S. Navy Public Works Center
FPO S.F. 96630-P.O. Box 188
Agan, Guam 96910

HAWAII

P.O. Box 50166
300 Ala Moana Boulevard-Room 6110
Honolulu, HI 96850

546-8331

HAWAII

Field Headquarters
4398D Loke Street
P.O. Box 1856
Lihue, Kauai, HI 96766

DIRECTORY: DISTRICT OFFICES OF THE U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION (Cont'd)

IDAHO

P.O. Box 2230
Idaho Falls, ID 83401

(208) 526-2438

ILLINOIS

P.O. Box 1026
102 E. Main Street
Urbana, IL 61820

(217) 398-5353

INDIANA

1819 North Meridian Street
Indianapolis, IN 46202

(317) 269-7101

IOWA

Federal Building - Room 269
P.O. Box 1230
Iowa City, IA 52240

(319) 337-4191

KANSAS

University of Kansas
Campus 1950 West Avenue A
Lawrence, KS 66045

(913) 864-4321

KENTUCKY

Federal Building - Room 572
600 Federal Place
Louisville, KY

(502) 582-5241

LOUISIANA

6554 Florida Boulevard
Baton Rouge, LA 70896

(504) 389-0281

MAINE

District Office in Mass.
26 Ganneston Drive
Augusta, ME 04430

(207) 623-4797

MARYLAND

208 Carroll Building
8600 Lasalle Road
Towson, MD

(301) 828-1535

MASSACHUSETTS

150 Causeway Street
Suite 1001
Boston, MA 02114

(617) 223-2822

MICHIGAN

6520 Mercantile Way - Suite 5
Lansing, MI 48910

(517) 372-1910

MINNESOTA

702 Post Office Building
St. Paul, MN 55101

(612) 725-7841

DIRECTORY: DISTRICT OFFICES OF THE U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION (Cont'd)

MISSISSIPPI

Federal Building, Suite 710
100 West Capitol Street
Jackson, MS 39201

(601) 969-4600

MISSOURI

Mail Stop 200
1400 Independence Road
Rolla, MO 65401

(314) 341-0824

MONTANA

Federal Building, Drawer 10076
Helena, MT 59601

(406) 559-5263

NEBRASKA

Federal Building/Courthouse - Room 406
100 Centennial Mall North
Lincoln, NE 58508

(402) 471-5082

NEVADA

Federal Building - Room 227
705 North Plaza Street
Carson City, NV 89701

(702) 882-1388

NEW HAMPSHIRE

Subdistrict - Dist. Off./Mass.
Federal Building - 210
55 Pleasant Street
Concord, NH 03301

NEW JERSEY

Federal Building - Room 436
402 E. State Street
P.O. Box 1238
Trenton, NJ 08607

(609) 989-2162

NEW MEXICO

Western Bank Building
505 Marquette, NW
Albuquerque, NM 87125

(505) 766-2246

NEW YORK

236 U.S. Post Office/Courthouse
P.O. Box 1350
Albany, NY 12201

(518) 472-3107

NORTH CAROLINA

Century Station - Room 436
Post Office Building
P.O. Box 2857
Raleigh, NC 27605

(919) 755-4510

NORTH DAKOTA

821 E. Interstate Avenue
Bismarck, ND 58501

(701) 255-4011

DIRECTORY: DISTRICT OFFICES OF THE U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION (Cont'd)

OHIO

975 West Third Avenue
Columbus, OH 43212

(614) 469-5553

OKLAHOMA

215 NW 3rd - Room 621
Oklahoma City, OK 73102

(405) 231-4256

OREGON

(Mail) P.O. Box 3203
Ship-830 NE Holladay Street, 97232
Portland, OR 97208

(503) 231-5242

PENNSYLVANIA

Federal Building - 4th Floor
P.O. Box 1107
Harrisburg, PA 17108

(717) 782-4514

PUERTO RICO

Building 652, Fort Buchanan
G.P.O. Box 4424
San Juan, PR 00936

(809) 783-4660

RHODE ISLAND

District Office in Mass.
Federal Building & U.S. P.O.
Room 224
Providence, RI 02903

(401) 528-4655

SOUTH CAROLINA

Strom Thurmond Federal Building
1835 Assembly Street - Suite 658
Columbia, SC 29201

(803) 765-5966

SOUTH DAKOTA

Federal Building - Room 308
200 4th Street, S.W.
Huron, SD 57350

(605) 352-8651

TENNESSEE

U.S. Courthouse
U.S. Federal Building A-413
Nashville, TN 37203

(615) 251-5424

TEXAS

Federal Building - 649
300 East 8th Street
Austin, TX 78701

(512) 397-5766

DIRECTORY: DISTRICT OFFICES OF THE U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION (Cont'd)

UTAH

Administrative Building - 106
1745 West 1700 South
Salt Lake City, UT 84104

(801) 524-5663

VERMONT

District Office in Mass.
U.S. Post Office/Courthouse
Rooms 330B and 330C
Montpelier, VT 05602

(802) 229-4500

VIRGINIA

200 West Grace Street - Room 304
Richmond, VA 23220

(804) 771-2427

WASHINGTON

1201 Pacific Avenue - Suite 600
Tacoma, WA 98402

(206) 593-6510

WEST VIRGINIA

Federal Building/U.S. Courthouse
500 Quarrier Street, East - Room 3017
Charlestown, WV 25301

(304) 343-6181

WISCONSIN

1815 University Building
Madison, WI 53706

(608) 262-2488

WYOMING

P.O. Box 1125
J.C. O'Mahoney Federal Center
2120 Capitol Avenue - Room 5017
Cheyenne, WY 82001

(307) 778-2220

DIRECTORY: REGIONAL OFFICES, U.S. FISH AND WILDLIFE SERVICE

1. Region 1

   U.S. Fish and Wildlife Service
   500 NE Multnomah Street
   Portland, OR 97232

   FTS 429-6150
   (503) 231-6150

2. Region 2

   U.S. Fish and Wildlife Service
   500 Gold Avenue, S.W.
   P.O. Box 1306
   Albuquerque, NM 87103

   (505) 766-2321

3. Region 3

   U.S. Fish and Wildlife Service
   Federal Bldg., Fort Snelling
   Twin Cities, MN 55111

   (612) 725-3500

4. Region 4

   U.S. Fish and Wildlife Service
   17 Executive Park, N.E.
   Atlanta, GA 30329

   (404) 526-4671

5. Region 5 (DE, MD, VA)*

   U.S. Fish and Wildlife Service
   Area Office
   1829 Virginia Street
   Annapolis, MD 24401

   FTS 922-2007/2008
   (301) 269-5448/5449

5. Region 5 (CT, ME, MA, NH, RI, VT)*

   U.S. Fish and Wildlife Service
   Area Office
   P.O. Box 1518
   Concord, NH 03301

   FTS 834-4717/4718

5. Region 5 (NJ, NY, PA, WV)*

   U.S. Fish and Wildlife Service
   Area Office
   1500 N. Second Street
   Harrisburg, PA 17102

   FTS 590-3743
   (717) 782-3743

6. Region 6

   U.S. Fish and Wildlife Service
   Denver Federal Center
   10597 W. Sixth Avenue
   P.O. Box 25486
   Denver, CO 80225

   (303) 234-2209

7. Alaska Area Office

   U.S. Fish and Wildlife Service
   1011 East Tudor Road
   Anchorage, AK 99503

   (907) 276-3800/545

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*No central regional office. Choose area office based on state which it serves as shown in parantheses.

State Agencies

State EPA Solid Waste Management Office

These agencies administer rules and regulations pertaining to solid waste disposal. They are generally operated under state legislation in accordance with the SWDA and the RCRA. They usually have the authority to regulate locations for solid waste disposal systems such as landfills. Proposed Army activities that will generate considerable amounts of solid waste should be coordinated with these agencies to determine regulations that apply to this disposal. Even if disposal is done by contract, the Army must determine if the contractor is operating under proper permits. Disposal of any hazardous materials should always be coordinated with these agencies. The directory on pp 45-51 provides the addresses and telephone numbers of state Solid Waste Management Offices.

State Geological Survey

State Geological Survey offices, generally located in the capital city of each state, can provide valuable information on soils, geologic formations, and underground water resources. The directory on pp 52-58 provides the addresses and telephone numbers of these offices.

State Fish and Game Office

The main office of the state Fish and Game Agency can provide valuable information on threatened and endangered fish and wildlife species in the state. The addresses and telephone numbers of these offices can be found in a telephone directory or by calling 555-1212 in the appropriate area code.

State Water Control Office

Every state has a water control office, generally in its capital. These agencies can provide information on surface water quality standards and groundwater quality and levels. The addresses and telephone numbers of these offices can be found in a telephone directory or by calling 555-1212 in the proper area code.

DIRECTORY: STATE SOLID WASTE AGENCIES

ALABAMA

Division of Solid Waste Management
Department of Public Services
434 Monroe Street
Montgomery, AL 36130

(205) 832-6728

ALASKA

Air and Solid Waste Management
Dept. of Environmental Conservation
Pouch O
Juneau, AK 99811

*Seattle FTS 399-0150
(907) 465-2635

ARIZONA

Department of Health Services
State Health Building, Room 202
1740 West Adams Street
Phoenix, AZ 85007

FTS 765-1130
(602) 255-1162

ARKANSAS

Department of Pollution Control and Ecology
P.O. Box 9583
8001 National Drive
Little Rock, AR 72219

(501) 562-7444

CALIFORNIA

Solid Waste Management Branch
Department of Health Services
744 P Street
Sacramento, CA 95814

FTS 552-2308
(916) 322-2308

COLORADO

Waste Management Division
Colorado Department of Health
4210 East 11th Avenue
Denver, CO 80220

(303) 320-8333

CONNECTICUT

Solid Waste Management Unit
Department of Environmental Protection
State Office Building
165 Capitol Avenue
Hartford, CT 06115

FTS 641-5712
(203) 566-5712

DELAWARE

Solid Waste Management Section
Department of Natural Resources and Environmental Control
Edward Tatnall Building
P.O. Box 14011, Room 203
Blue Hen Mall
Dover, DE 19901

(302) 736-4781

*FTS - Federal telephone system

DISTRICT OF COLUMBIA

Solid Waste Management Administration
Dept. of Environmental Services
5000 Overlook Avenue, SW
Washington, D.C. 20032

(202) 767-8176

FLORIDA

Solid Waste Section
Department of Environmental Regulation
Twin Towers Office Building, Rm. 421
2600 Blair Stone Road
Tallahassee, FL 32301

(904) 488-0300

GEORGIA

Land Protection Branch
Environmental Protection Division
Department of Natural Resources
270 Washington Street SW, Room 822
Atlanta, GA 30334

(404) 656-2833

GUAM

EPA, Government of Guam
P.O. Box 2999
Agana, Guam 96910

Overseas Operator
(Commerical: Call 646-8863)

HAWAII

Environmental Health Division
Department of Health
P.O. Box 3378
Honolulu, HI 96801

California FTS Operator 556-0220
(808) 548-4139

IDAHO

Solid Waste Management Section
Department of Health and Welfare
State House
Boise, ID 83720

FTS 554-4064
(208) 334-4064/384-2287

ILLINOIS

Division of Land and Noise
Pollution Control
Environmental Protection Agency
2200 Churchill Road, RM A-104
Springfield, IL 62706

FTS 956-6760
(217) 782-6760

INDIANA

Land Pollution Control Divison
State Board of Health
1330 W. Michigan Street, Rm. A-304
Indianapolis, IN 46206

(317) 633-0994

IOWA

Air & Land Quality Division
Department of Environment Quality
Henry A. Wallace Building
900 East Grand Street, 3rd Floor
Des Moines, IA 50319

(FTS 841-8853
(515) 281-8853

KANSAS

Bureau of Environmental Sanitation
Department of Health and Environement
Forbes Field, Building 321
Topeka, KS 66620

(913) 862-9360, ext. 290

DIRECTORY: STATE SOLID WASTE AGENCIES (Cont'd)

KENTUCKY

Division of Waste Management
Bureau of Environmental Protection
Dept. for Natural Resources and
 Environmental Protection
18 Reilly Road
Frankfort, KY 40601

FTS 351-6716
(502) 564-6716

LOUISIANA

Solid Waste Division
Department of Natural Resources
P.O. Box 44396
Baton Rouge, LA 70804

(504) 342-1227

MAINE

Division of Solid Waste
Department of Environmental
 Protection
State House, Station 17
Augusta, ME 04333

FTS 868-2111
(207) 289-2111

MARYLAND

Waste Management Administration
Department of Health and Mental
 Hygiene
201 West Preston Street, Room 212
Baltimore, MD 21201

(301) 833-5740/3123

MASSACHUSETTS

Bureau of Solid Waste Disposal
Dept. of Environmental Management
Leverett Saltonstall Bldg. Rm 1905
100 Cambridge Street
Boston, MA 02202

(617) 727-4293

MICHIGAN

Environmental Protection Bureau
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909

FTS 253-7919
(517) 373-7917

MINNESOTA

Solid and Hazardous Waste Division
Pollution Control Agency
1935 West County Road, B-2
Roseville, MN 55113

(612) 297-2735

MISSISSIPPI

Division of Solid Waste Management
Bureau of Pollution Control
Department of Natural Resources
P.O. Box 10385
Jackson, MS 39209

(601) 961-5171

MISSOURI

Waste Management Program
Department of Natural Resources
State Office Building
P.O. Box 1368
Jefferson City, MO 65102

(314) 751-3241

MONTANA

Solid Waste Management Bureau
Department of Health and Environmental Sciences
Cogswell Building, Room A201
Helena, MT 59602

FTS 587-2821
(406) 449-2821

NEBRASKA

Water and Waste Management Division
State House Station
P.O. Box 94877
Lincoln, NE 68509

FTS 541-2148
(402) 471-2186

NEVADA

Waste Management Program
Division of Environmental Protection
Department of Conservation and Natural Resources
Capital City, NV 89701

(702) 885-4670

NEW HAMPSHIRE

Bureau of Solid Waste
Department of Health and Welfare
Health and Welfare Building
Hazen Drive
Concord, NH 03301

(603) 271-4608

NEW JERSEY

Solid Waste Administration
Divison of Environmental Quality
Department of Environmental Protection
32 East Hanover Street
Trenton, NJ 08625

FTS 567-9877
(609) 292-9877

NEW MEXICO

Community Support Services Bureau
Environmental Protection Division
New Mexico Health and Environmental Dept.
P.O. Box 968
Santa Fe, NM 87504

FTS 476-5271, ext. 282
(505) 457-5271, ext. 282

DIRECTORY: STATE SOLID WASTE AGENCIES (Cont'd)

NEW YORK

Division of Solid Waste
Dept. of Environmental Conservation
50 Wolf Road, Room 209
Albany, NY 12233

FTS 567-3254
(518) 467-3254

NORTH CAROLINA

Solid and Hazardous Waste Mgt. Branch
Division of Health Services
Department of Human Resources
P.O. Box 2091
Raleigh, NC 27602

(919) 733-2178

NORTH DAKOTA

Division of Environmental Waste
Management and Research
Department of Health
1200 Missouri Avenue, 3rd Floor
Bismark, MD 58505

(701) 224-2366

OHIO

Office of Land Pollution Control
Environmental Protection Agency
P.O. Box 1049
Columbus, OH 43216

FTS 942-8934
(614) 466-8934

OKLAHOMA

Industrial and Solid Waste
Services
Department of Health
P.O. Box 53551
1000 NE 10th Street, Room 803
Oklahoma City, OK 73152

(405) 271-5338

OREGON

Solid Waste Management Division
Department of Environmental
Quality
P.O. Box 1760
522 SW Fifth Avenue
Portland, OR 97207

FTS 424-5913
(503) 229-5913

PENNSYLVANIA

Bureau of Solid Waste Management
Department of Environmental
Resources
Fulton Building, 8th Floor
P.O. Box 2063
Harrisburg, PA 17120

FTS 637-9870
(717) 787-7383

RHODE ISLAND

Solid Waste Management Program
Department of Environmental Mgmt.
204 Cannon Building
75 Davis Street
Providence, RI 02908

FTS 277-2797
(401) 277-2797

DIRECTORY: STATE SOLID WASTE AGENCIES (Cont'd)

SOUTH CAROLINA

Bureau of Solid and Haz. Waste Mgt.
Department of Health and
Environmental Control
J. Marion Simms Building
2600 Bull Street
Columbia, SC 29201

(803) 758-5681

SOUTH DAKOTA

Division of Environmental Health
Department of Health
Joe Foss Building
Pierre, SD 57501

(605) 773-3329

TENNESSEE

Division of Solid Waste Management
Bureau of Environmental Services
Tennessee Department of Public
Health
150 9th Avenue North
Nashville, TN 37203

FTS 853-3424
(615) 741-3424

TEXAS

Bureau of Solid Waste Management
Texas Department of Health
1100 West 49th Street, T-602
Austin, TX 78756

(512) 458-7271

UTAH

Bureau of Solid and Hazardous
Waste Management
Department of Health
P.O. Box 2500
150 West North Temple
Salt Lake City, UT 84110

(801) 533-4145

VERMONT

Air and Solid Waste Programs
Agency of Environmental
Conservation
State Office Building
P.O. Box 489
Montpelier, VT 05602

FTS 832-3395
(802) 828-3395

VIRGIN ISLANDS

Division of Natural Resources Mgt.
Department of Conservation and
Cultural Affairs
P.O. Box 4340, Charlotte Amalie
St. Thomas, VI 00801

D.C. Overseas Operator 472-6620
(809) 774-6420

VIRGINA

Division of Solid and Haz. Waste Mgt.
Virginia Deparment of Health
Madison Building
109 Governor Street
Richmond, VA 23219

FTS 936-5271
(804) 786-5271

DIRECTORY: STATE SOLID WASTE AGENCIES (Cont'd)

WASHINGTON

Solid Waste Management Division
Department of Ecology
Olympia, WA 98504

FTS 459-6317
(206) 753-6317

WISCONSIN

Bureau of Solid Waste Management
Department of Natural Resources
P.O. Box 7921
Madison, WI 53707

FTS 366-1327
(608) 266-1327

WEST VIRGINIA

Division of Natural Resources
Department of Natural Resources
1201 Greenbriar Street
East Charleston, WV 25311

(304) 348-5935

WYOMING

Solid Waste Management Program
Department of Environmental Quality
Equality State Bank Building
401 West 19th Street
Cheyenne, WY 82002

FTS 328-7752
(307) 777-7752

DIRECTORY: STATE GEOLOGISTS

(From the 1980 Directory of the Association of American State Geologists)

ALABAMA

Thomas J. Joiner
Geol. Survey of Alabama
P.O. Drawer O
University, AL 35486

(205) 349-2852

ALASKA

Ross G. Schaff
Div. of Geology and
Geophysical Surveys
3001 Porcupine Drive
Anchorage, AK 99501

(907) 279-1433

ARIZONA

Larry D. Fellows
Bureau of Geology and
Mineral Technology
Geol. Survey Branch
845 N. Park Avenue
Tucson, AZ 85719

(602) 626-2733

ARKANSAS

Norman F. Williams
Arkansas Geol. Commission
Vardelle Parham Geol. Center
3815 W. Roosevelt Road
Little Rock, AR 72204

(501) 371-1488

CALIFORNIA

F. Davis
Div. of Mines and Geology
Calif. Dept. of Conservation
1416 9th Street, Room 1341
Sacramento, CA 95814

(916) 445-1923

COLORADO

John W. Rold
Colorado Geological Survey
1313 Sherman St., Room 715
Denver, CO 80203

(303) 893-2611

CONNECTICUT

Hugo F. Thomas
Conn. Geol. and Natural
History Survey
State Office Bldg., Room 553
165 Capitol Avenue
Hartford, CT 06115

(203) 566-3540

DELAWARE

Robert R. Jordan
Delaware Geological Survey
University of Delaware
Newark, DE 19711

(302) 738-2833

DIRECTORY: STATE GEOLOGISTS (Cont'd)

FLORIDA

Charles W. Hendry, Jr.
Bureau of Geology
903 W. Tennessee St.
Tallahassee, FL 32304

(904) 488-4191

GEORGIA

William McLemore
Geol. and Water
Resources Division
Dept. of Natural Resources
19 Dr. Martin Luther King,
Jr. Drive, S.W.
Atlanta, GA 30334

(404) 656-3214

HAWAII

Robert T. Chuck
Div. of Water and Land Dev.
P.O. Box 373
Honolulu, HI 96809

(808) 548-7533

IDAHO

Maynard M. Miller
Idaho Bur. of Mines
and Geology
Moscow, ID 83843

(208) 885-6785

ILLINOIS

Jack A. Simon
Illinois State Geological Survey
121 Natural Resources Bldg.
Urbana, IL 61801

(217) 333-5111

INDIANA

John B. Patton
Dept. of Natural Resources
Indiana Geological Survey
611 North Walnut Grove
Bloomington, IN 47401

(812) 337-2862

IOWA

Stanley C. Grant
Iowa Geological Survey
123 N. Capitol
Iowa City, IA 52242

(319) 338-1173

KANSAS

William W. Hambleton
State Geol. Survey of Kansas
Raymond C. Moore Hall
1930 Avenue A. Campus West
Lawrence, KS 66044

(913) 864-3965

DIRECTORY: STATE GEOLOGISTS (Cont'd)

KENTUCKY

Donald C. Haney
Kentucky Geol. Survey
University of Kentucky
311 Breckinridge Hall
Lexington, KY 40506

(606) 622-3270

LOUISIANA

Charles G. Groat
Louisiana Geol. Survey
Box G, Univ. Station
Baton Rouge, LA 70893

(504) 342-6754

MAINE

Walter Anderson
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State Off. Bldg., Rm. 211
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Army Agencies/Organizations

Army Environmental Office

This is the principal staff office at the Army Headquarters level that manages the Army environmental program and promulgates AR 200-1. This office can provide information on solid waste management policies, regulations, and budgeting for disposal facilities. Information can be obtained by contacting, Office, Assistant Chief of Engineers, Army Environmental Office, DAEN-ZCE, Room 1E686, The Pentagon, Washington, DC 20301. Telephone: (202) 694-4269; Autovon: 224-4269.

Utilities Branch, Facilities Engineering Division

The Utilities Branch is the proponent for AR 420-47, which provides operational guidance on solid waste disposal. This office can provide assistance related to programming and budgeting for disposal facilities and technical aspects of landfill design and operation. Information is available from Office, Chief of Engineers, Facility Engineering Division, Utilities Branch, 20 Massachusetts Avenue, NW, Washington, DC 20314-1000. Telephone: (202) 272-0588; Autovon: 285-0588.

U.S. Army Construction Engineering Research Laboratory (USA-CERL)

USA-CERL has extensive environmental engineering capability for all aspects of pollution abatement. In the area of solid waste management, technical expertise is available on sanitary landfill design and operation, landfill liners and covers, leachate collection and treatment, and landfill gas control. USA-CERL can also deploy a mobile water analysis laboratory with the equipment needed to perform on-site chemical analysis. Individuals having engineering and scientific background and experience are available for on-site investigations upon request.

For more information, contact USA-CERL, ATTN: Water Quality Management Team (Dr. Stephen Maloney), P.O. Box 4005, Champaign, IL 61820-1305. Telephone toll free: 1-800-USA-CERL (outside Illinois); 1-800-252-7122 (within Illinois); FTS: 958-7740.

U.S. Army Environmental Hygiene Agency (AEHA)

The Groundwater and Solid Waste Branch of AEHA helps Department of Defense installations evaluate existing and proposed solid waste management programs. This assistance includes two major services: (1) on-site evaluation of present sanitary landfill operational techniques and (2) hydrogeologic and soils analysis for recommending new sanitary landfill sites, as required for obtaining a state sanitary landfill permit. AEHA will also locate and/or install monitoring wells up to a 120-ft depth to determine groundwater contamination (i.e., leachate). Soil samples are analyzed at Aberdeen Proving Ground, MD, for permeabilities, densities, soil classification according to the Unified Soil Classification System, specific gravity, and cation exchange capacity, etc.

These services can be requested by the installation Major Command (MACOM) through the Commander, U.S. Army Health Services Command, ATTN: HSPA-P, Fort Sam Houston, TX 78231, with an information copy to Commander, U.S. Army Environmental Hygiene Agency, ATTN: HSE-ES, Aberdeen Proving Ground, MD 21010. The Commander, U.S. Army Health Services Command, will endorse the request with recommended action to the AEHA; the agency will then program requests, by priority, by

fiscal year and quarter. All written requests should include an installation point of contact and telephone number.

Telephone consultation can be obtained by contacting the Chief of the Groundwater and Solid Waste Branch at (301) 671-2024 or Autovon: 584-2024.

U.S. Army Engineer Waterways Experiment Station (WES)

WES has been involved in several research projects to evaluate problems associated with the generation of leachate and gas in landfills. In cooperation with the USEPA, WES has examined the leachate from mixed hazardous industrial and municipal wastes and conducted extensive field investigations on power generation wastes, municipal landfills, and industrial waste landfills. WES has also conducted field gas surveys and established three gas and leachate monitoring systems at Fort Belvoir, VA.

WES has an extensive information base on landfill design, leachate and gas control, and hazardous waste disposal. More than 30 publications on municipal and hazardous waste disposal technology have been generated from the USEPA and Army-sponsored research efforts at WES.

Point of Contact: Dr. Phillip G. Malone, P.O. Box 631, Vicksburg, MS 39180. Telephone: (601) 634-3960; FTS: 542-3960.

Huntsville Engineer Division (HND)

The Corps of Engineers' Huntsville Division has established and maintains a data file of printed material unique to pollution abatement technology. The database contains publications in several areas: pollution abatement techniques, processes, and equipment; state and Federal pollution laws; lessons learned; and project costs. The database also provides sources of expertise, including universities, government, industry, and associations, as well as information on nongovernment pollution abatement facilities similar to those needed by the Army. This system provides comprehensive information on air and water pollution control technology and limited information on solid waste disposal technologies and procedures.

An installation may request, through its MACOM, assistance from HND on a reimbursable basis. The division maintains a file on all Army landfills (past and present) and can provide assistance in applying for a landfill operating permit.

Point of Contact: Office, Assistant Division Engineer, P.O. Box 1600, Huntsville, AL 35807-4301. Telephone: (205) 895-5370; Autovon: 742-5370.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA)

USATHAMA conducts installation assessments to search for, identify, and assess actual or potential chemical, biological, or radiological contamination and/or migration. It does this by reviewing records and interviewing present and former employees. The agency also conducts installation surveys to establish environmental contamination levels and verifies whether there is migration by determining subsurface water movement patterns.

USATHAMA is the lead DOD agency for developing pollution abatement/contaminant technology for migrating contaminants and for contamination problems on excess properties. The agency also has design and process engineering expertise in these areas.

USATHAMA has developed a data management system for environmental contamination at assigned Army installations. Interactive programs provide computer mapping of sampling points, groundwater head, chemical concentration contours, and borelog profiles. In addition to the reduction of raw data, USATHAMA can conduct bibliographic searches of open literature databases. Chemical and physical properties of compounds can be retrieved through telecommunication links with the National Institute of Health and with the USEPA. The agency maintains a registry of contamination from past operations, at a summary level, for each assigned Army installation.

Point of Contact: John K. Bartel, Aberdeen Proving Ground, MD 21010, DRXTH-TE. Telephone: (301) 671-2466; Autovon: 584-2466.

7 SUMMARY

This report has provided information on landfill leachate management for installation environmental coordinators and other management personnel. This information will be useful as guidance in identifying leachate problems and in locating data and technical assistance for solving these problems. Information is also provided to help personnel who must establish a new sanitary landfill requiring leachate control or investigate possible problems with older or inactive landfills.

Specific information was provided on regulatory requirements and responsibilities, landfill design and operation, leachate and gas production and control in both old and new landfills, and sources of information and assistance.

Metric Conversion Factors

1 lb = 0.453 kg
1 sq yd = 0.836 m^2
1 gal = 3.785 L
1 ft = 0.304 m
1 mil = 0.0254 mm
1 in. = 25.4 mm
°C = (°F-32) (5/9)

APPENDIX A:

LIST OF PRIORITY POLLUTANTS

	Compound name	Chemical abstract service number
Metals and cyanide	Antimony, total	7440-36-0
	Arsenic, total	7440-38-2
	Beryllium, total	7440-41-7
	Cadmium, total	7440-43-9
	Chromium, total	7440-47-3
	Copper, total	7440-50-8
	Lead, total	7439-97-6
	Mercury, total	7439-97-6
	Nickel, total	7440-02-0
	Selenium, total	7782-49-2
	Silver, total	7440-22-4
	Thallium, total	7440-28-0
	Zinc, total	7440-66-6
	Cyanide, total	57-12-5
Dioxin	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	1764-01-6
Volatile compounds	Acrolein	107-02-8
	Acrylonitrile	107-13-1
	Benzene	71-43-2
	Bromoform	75-25-2
	Carbon tetrachloride	56-23-5
	Chlorobenzene	108-90-7

	Compound name	Chemical abstract service number
	Chloroethane	75-00-3
	2-Chloroethyvinyl ether	110-75-8
	Chloroform	67-66-3
	1,1-Dichloroethane	75-34-3
	1,2-Dichloroethane	107-06-2
	1,1-Dichloroethylene	75-35-4
	1,2-Dichloropropane	78-87-5
	1,3-Dichloropropylene	542-75-6
	Ethylbenzene	1-41-4
	Methyl bromide	74-83-9
	Methyl chloride	75-09-2
	1,1,2,2-Tetrachloroethane	79-34-5
	Tetrachloroethylene	127-18-4
	Toluene	108-88-3
	1,2-Trans-dichloroethylene	156-60-5
	1,1,1-Trichloroethane	71-55-6
	1,1,2-Trichloroethane	79-00-5
	Trichloroethylene	79-01-6
	Vinyl chloride	75-01-4
Acid compounds	2-Chlorophenol	95-57-8
	2,4-Dichlorophenol	120-83-2
	2,4-Dimethylphenol	105-67-9
	4,6-Dinitro-o-cresol	534-52-1
	2,4-Dinitrophenol	51-28-5
	2-Nitrophenol	88-75-5
	4-Nitrophenol	100-02-7

	Compound name	Chemical abstract service number
	p-Chloro-m-cresol	59-50-7
	Pentachlorophenol	87-86-5
	Phenol	108-95-2
	2,4-6-Trichlorophenol	88-06-2
Base/neutral compounds	Acenaphthene	83-32-9
	Acenaphthylene	208-96-8
	Anthracene	120-12-7
	Benzidine	92-87-5
	Benzo[a]anthracene	56-55-3
	Benzo[a]pyrene	50-32-8
	Benzo[b]fluoranthene	205-99-2
	Benzo[ghi]perylene	191-24-2
	Benzo[k]fluoranthene	207-08-9
	Bis (2-Chloroethoxy) methane	111-91-1
	Bis (2-chloroethyl) ether	111-44-4
	Bis (2-Chloroisopropyl) ether	102-60-1
	Bis (2-ethylhexyl) phthalate	117-81-7
	4-Bromophenyl phenyl ether	101-55-3
	Butyl benzyl phthalate	85-68-7
	2-Chloronaphthalene	91-58-7
	4-Chlorophenyl phenyl ether	7005-72-3
	Chrysene	218-01-9
	Dibenzo [a,h]anthracene	53-70-3
	1,2-Dichlorobenzene	95-50-1
	1,3-Dichlorobenzene	541-73-1

Compound name	Chemical abstract service number
1,4-Dichlorobenzene	106-46-71
3,3-Dichlorobenzidine	91-94-1
Diethyl phthalate	84-66-2
Dimethyl phthalate	131-11-3
Di-n-Butyl phthalate	84-74-2
2,4-Dinitrotoluene	121-14-2
2,6-Dinitrotoluene	606-2-2
Di-n-Octyl phthalate	117-84-0
1,2-Diphenylhydrazine (as azobenzene)	122-66-7
Fluoranthene	206-44-0
Fluorene	86-73-7
Hexachlorobenzene	118-74-1
Hexachlorobutadiene	87-68-3
Hexachlorocyclopentadiene	77-47-4
Hexachloroethane	67-72-1
Indeno[1,2,3-cd]pyrene	193-39-5
Isophorone	78-59-1
Naphthalene	91-20-3
Nitrobenzene	98-95-3
N-Nitrosodimethylamine	62-75-9
N-Nitrosodi-N-propylamine	621-64-7
N-Nitrosodiphenylamine	86-30-6
Phenanthrene	85-01-8
Pyrene	129-00-0
1,2,4-Trichlorobenzene	120-82-1

	Compound name	Chemical abstract service number
Pesticides	Aldrin	309-00-2
	alpha-BHC	319-84-6
	beta-BHC	319-85-7
	gamma-BHC	58-89-9
	delta-BHC (Lindane)	319-86-8
	Chlordane	57-74-9
	4,4-DDT	50-29-3
	4,4-DDE	72-55-9
	4,4-DDD	72-54-8
	Dieldrin	60-57-1
	alpha-Endosulfan	115-29-7
	beta-Endosulfan	115-29-7
	Endosulfan sulfate	1031-07-8
	Endrin	72-20-8
	Endrin aldehyde	7421-93-4
	Heptachlor	76-44-8
	Heptachlor epoxide	1024-57-3
	PCB 1241	53469-21-9
	PCB 1254	11097-69-1
	PCB 1221	11104-28-2
	PCB 1232	11141-16-5
	PCB 1248	12672-29-6
	PCB 1260	11096-82-5
	PCB 1016	12674-11-2
	Toxaphene	8001-35-2

APPENDIX B:

REMEDIAL ACTION CHECKLIST

FACTOR	EVALUATION (YES/NO)	COMMENTS
A. PROBLEM IDENTIFICATON		
1. Seeps & Discharge		
2. Vegetative Stress		
3. Water Pollution		
4. Illness Reports		
B. PRELIMINARY TESTS		
1. Chemical/Biological Tests (Leachate)		
a. pH		
b. Conductivity		
c. Chloride		
d. Sulfate		
e. Iron		
f. Sodium		
g. COD		
h. TOC		
i. BOD		
j. Coliforms		
2. Chemical/Biological Tests (Water Source)		
a. Water Quality Standards		
b. Drinking Water Standards		
3. Evaluation of Test Results		
4. Environmental Threat		
C. INITIAL SITE SURVEY		
1. Records Search		
a. General maps		
b. Site maps		
c. Aerial photos		
d. Soil maps		
e. Hydrogeological maps		
f. Waste disposal records		
g. Interviews		

FACTOR	EVALUATION (YES/NO)	COMMENTS
2. ON-SITE INVESTIGATION		
a. On-foot inspection		
b. Aerial observation		
c. Augered test holes		
d. Well sample tests		
3. ANALYSIS OF INVESTIGATION FINDINGS		
a. Estimate of Leachate Volume		
b. Significant Constituents		
1) Organic		
2) Inorganic		
c. Potential Receptors		
1) Aquatic Life		
2) Aquifiers		
3) Drinking water supplies		
d. Future Action		
1) End Investigation		

FACTOR	EVALUATION (YES/NO)	COMMENTS
2) Continue Investigation		
D. DETAILED SITE INVESTIGATION		
1. Landfill site boundaries, Depth, Hydrogeologic Conditions		
a. Resistivity/Electro-Magnetic Survey		
b. Conductivity Survey		
c. Groundwater Flow		
2. Monitoring Wells		
a. Number		
b. Location		
c. Depth		
3. Geophysical Investigation		
a. Groundwater Flow		
1) Contractor		
2) Funds		
b. Water Quality Test Parameters		
1) Testing Agency		

FACTOR	EVALUATION (YES/NO)	COMMENTS
2) Funds		
4. Test Analysis and Evaluation		
a. Problems		
b. Corrective Action		
E. REMEDIAL ACTION		
1 Water Quality Standards		
2. Quick Fix Measures		
a. Reshape landfill cap & drainage		
b. Install new cap		
c. Install drains and collection system		
3. Major Construction		
a. Slurry -Trench		
b. Grout Curtain		
c. Sheet piling		
d. Bottom grouting		
e. Well points extraction well		

FACTOR	EVALUATION (YES/NO)	COMMENTS
4. Leachate Treatment		
a. Leachate Volume		
1) Estimate		
2) Lagoon		
3) Sewage Treatment Plant		
b. New Treatment Facility		
1) Ammonia Stripping		
2) Carbon Adsorption		
3) Chemical Oxidation		
4) Ion Exchange		
5) Precipitation/ Flocculation/ Sedimentation		
6) pH Adjustment		
7) Reverse Osmosis		
8) Wet air Oxidation		

FACTORS FOR ADDRESSING LEACHATE PROBLEMS

Factors	Identification
A. Problem Identification	
1. Seeps and discharges	Has an on-site inspection of the landfill revealed evidence of seeps or discharges of fluid at the edge of the known or suspected landfill? Is the liquid dark-colored and does it have a foul odor?
2. Vegetative stress	Has an on-site inspection of the landfill revealed dead grass, weeds, or shrubs in the vicinity of seeps? (Note that dead vegetation may also result from landfill gas.)
3. Water pollution	Has an on-site inspection of the landfill revealed dead aquatic vegetation, fish kills, or discoloration in surface water caused by seepage or leachate discharge?
4. Illness reports	Have there been any recent reports or complaints about the taste of well water from residents or communities in the vicinity of the landfill? Have there been reports or complaints about people or domestic animals becoming sick from using surface or groundwater in the vicinity of the landfill?
B. Preliminary tests	
1. Chemical/biological tests (leachate) (Tests performed locally or by AEHA or USATHAMA) a pH b. Conductivity c. Chloride d. Sulfate e. Iron f. Sodium g. COD h. TOC i. VOCs j. Coliform bacteria	Does a preliminary laboratory analysis of a sample taken from a landfill discharge reveal abnormal levels of the following substances or conditions?

Factors	Identification
2. Chemical/biological test of water source (Tests to be performed locally or by AEHA or USATHAMA) a. Water quality criteria b. Drinking water standard	Does a preliminary laboratory test of water samples from wells or surface water indicate unusual levels of organic or inorganic substances? Are any priority pollutants present? (See Appendix A). Have drinking water quality standards been exceeded? (See Appendix C).
3. Evaluation of test results (Refer task to AEHA or USATHAMA)	Do the results of the laboratory tests indicate that the discharge is probably leachate?
4. Environmental threat (Consult with AEHA or USATHAMA)	Does a preliminary analysis of the situation and test results indicate a possible threat to the environment, water supplies, or human and animal health?
C. Initial Site Survey (USATHAMA Phase I I&R Study)	
1. Records search a. General maps b. Site maps c. Aerial maps d. Soil maps e. Hydrogeologic maps f. Waste disposal records g. Interview of sanitation workers (active and retired)	Does a search of installation historical records provide definitive information about the landfill boundaries, depth, contents, and subsurface conditions? (Consider the sources listed).
2. On-site investigation a. On-foot inspection b. Aerial observation c. Inspection of contents of augered test holes (if required) d. Testing of liquid samples from selected test wells at landfill perimeter (if required)	Is there correlation between information obtained from the records search and physical conditions at the site?

Factors	Identification
3. Analysis of investigation findings	Is there evidence that sufficient leachate containing toxic substances is being produced and that it has or could pose an environmental threat?
a. Estimate of leachate volume	
b. Significant chemical constituents in leachate (1) Organic substances (2) Inorganic substances	Do tests indicate the presence of toxic substances harmful to humans, animals, and the environment?
c. Actual and potential receptors of pollutants (1) Aquatic life (2) Aquifers (3) Drinking water supplies	Are there receptors in the vicinity of the landfill that are or could be adversely affected by leachate releases?
d. Future action (1) End investigation (2) Continue investigation	Is the information conclusive enough to reach a decision of "no impact," or is further site investigation required?

D. Detailed Site Inspection (USATHAMA Phase II I&R Inspection)

1. Landfill site boundaries, depth, and hydrogeologic conditions	Is additional information needed to identify landfill boundaries, depth of waste, soil and geologic conditions, and groundwater? Should the following surveys be performed?
a. Resistivity survey/ electromagnetic survey	Is WES available to perform either a a resistivity or electromagnetic survey.
b. Conductivity survey	Can existing monitoring wells be used for a conductivity survey?
4. Test analysis and evaluation	Using the additional field data gathered, does a leachate pollution problem exist? Can specific conditions be identified that need correction?
a. Problems b. Corrective action	

E. Remedial Action (USATHAMA, Phase III I&R Report)

1. Water Quality Standards	Are there any water quality standards prescribed by the state that must be met once remedial action has been taken?

Factors	Identification
2. Quick-fix measure	Can "quick-fix," relatively inexpensive remedial measures be initiated to reduce extent of pollution? Have the following measures been considered?
a. Reshape landfill cap and surface drainage b. Install new cap c. Install drains and collection system	
3. Major construction	Is major construction required to block groundwater flow through buried waste or protect a drinking water aquifer? Have the following technologies and their costs been considered?
a. Slurry-trench, cutoff wall b. Grout curtain c. Sheet piling d. Bottom grouting e. Well points/extraction well	
4. Leachate treatment	Is leachate to be extracted, and will it have to be treated prior to disposal?
a. Leachate volume	Is there sufficient leachate to justify a separate treatment facility?
(1) Estimate	
(2) Lagoon	Is a lagoon required?
(3) Sewage treatment plant (STP)	Can disposal be accomplished at the installation STP?
b. New treatment facility	Is a new leachate treatment facility required? Which of the following processes can remove pollutants at least cost?
(1) Ammonia stripping (2) Carbon adsorption (3) Chemical oxidation (4) Ion exchange (5) Precipitation/ flocculation/ sedimentation (6) pH adjustment (7) Reverse osmosis (8) Wet air oxidation	
c. Groundwater flow	Can existing monitoring wells be used for groundwater flow measurements?

Factors	Identification
5. Monitoring wells a. Number b. Location c. Depth	Are additional monitoring wells required to obtain essential information? Where should they be located? How deep should they be?
6. Geophysical investigations	Are additional field tests needed to obtain detailed information about groundwater pollution conditions?
a. Groundwater flow (1) Contractor (2) Funds	Are the necessary resources (contractor) and funds available to conduct tests?
b. Water quality test parameters	Are water quality test parameters identified by state or Army authorities?
(1) Testing agency	Is a contractor or Army agency (AEHA or USATHAMA) available to perform tests?
(2) Funds	Are funds available for water quality testing?

APPENDIX C:

NATIONAL PRIMARY DRINKING WATER STANDARDS

Contaminant	
Inorganic chemical	**Maximum level (mg/L)**
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Fluoride	4.0
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05

Organic	**Proposed maximum level (mg/L)**
Benzene	0.005
Vinyl chloride	0.001
Carbon tetrachloride	0.005
1,2-Dichloroethane	0.005
Trichloroethylene	0.005
1,1-Dichloroethylene	0.007
1,1,1-Trichloroethane	0.20
p-Dichlorobenzene	0.75

GLOSSARY

Organizations

AEHA:	Army Environmental Hygiene Agency
EPA:	Environmental Protection Agency
USA-CERL:	U.S. Army Construction Engineering Research Laboratory
USATHAMA:	U.S. Army Toxic and Hazardous Materials Agency
WES:	U.S. Army Engineer Waterways Experiment Station (Corps of Engineers)

Abbreviations/Terms

leachate: liquid emanating from a land disposal cell that contains dissolved, suspended, and/or microbial contaminants from a solid waste.

aerobic decomposition: the decay or breaking down of organic material in the presence of "free" or dissolved oxygen.

anaerobic decomposition: the decay or breaking down of organic material in an environment containing no "free" or dissolved oxygen.

BOD: biochemical oxygen demand. The amount of oxygen that microorganisms use in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. Organic matter serves as food for the bacteria, and energy results from its oxidation. The oxygen use is measured under dark incubation at 20°C and usually for 5 days.

cadmium: a white, ductile, metallic, toxic element used for coating small steel articles as a protection against corrosion.

CFR: Code of Federal Regulations.

cover: soil used to cover compacted solid waste in a sanitary landfill; generally free of large objects that would hinder compaction.

COD: chemical oxygen demand. A measure of the oxygen-consuming capacity of inorganic and organic matter present in wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/L during a specific test. Results are not necessarily related to the biochemical oxygen demand, because the chemical oxidant may react with substances that bacteria do not stabilize.

DERF: Defense Environmental Restoration Fund.

evapotranspiration: the sum of water removed by vegetation and that lost by evaporation.

fly ash: accumulated particulates removed from large boiler plant combustion gases using either electrostatic precipitators or scrubbers.

groundwater: water occurring in the zone of saturation in an aquifer or soil.

hydrogen sulfide: a gas characterized by a rotten egg odor.

methane: an odorless, colorless, nonpoisonous, explosive gas.

NPDES permit: National Pollutant Discharge Elimination System permit; the regulatory agency document designed to control all discharges of pollutants from point sources into U.S. waterways.

permeability: the quality or state relating to the ease with which a porous medium conducts or transmits fluids.

pH: negative logarithm of hydrogen ion concentration; indicator of a liquid's acidity or alkalinity.

pollution: any change in the natural state of water that interferes with its beneficial reuse or causes failure to meet water quality requirements.

ppm: parts per million.

refuse: all solid waste of a community and semi-liquid or wet waste with insufficient liquid content to be free-flowing. Depending on the source, the refuse may be identified as domestic, commercial, or industrial refuse.

run-on: surface flow from precipitation that enters a site from an adjacent area.

run-off: the portion of precipitation falling on an area that remains on the ground surface and is returned to a stream as surface flow.

sewage sludge: the settleable solids separated from sewage during the treatment process.

surface water: a body of water whose top surface is exposed to the atmosphere; includes a flowing body as well as a pond or lake.

total organic carbon (TOC): the total amount of carbon found in all chemicals within the sample which was either produced by plants or animals or synthesized by humans from petroleum-based products.

VOC's: volatile organic compounds (VOC). Carbon compounds such as industrial solvents and fuel oils which easily vaporize.

water table: the surface of underground, gravity-controlled water.

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